Industrial QUALITY CONTROL

VOL. IV MARCH, 1948 NO. 5

CONVENTION ISSUE

Left to right: Dr. A. E. R. Westman, Convention Dinner Speaker; George D. Edwards, President, ASQC; Brigadier General Herman F. Safford, Member of Advisory Council, ASQC. (See page 14)

AMERICAN SOCIETY FOR QUALITY CONTROL

The Backbone of Cost Saving Dimensional Control

If you are manufacturing mechanical elements, close dimensional control will save you assembly time because accurately sized parts fit together quickly. Applied directly at the machine, proper gages save you scrap losses and much machine time. When all the elements of a mechanical assembly are held accurately within tolerance, that assembly gives superior performance in service.

Around Sheffield instruments and gages have been developed some of the most effective dimensional quality control policies in the manufacturing field. Let us send you descriptive literature on cost saving equipment—it may lead to solving your inspection problems.

THE PRECISIONAIRE is a flow type air gage for measuring true and average diameter, bellmouth, out-of-round for through and blind holes—concentricity, squareness, straightness and parallelism—also many external dimensions. Write for catalog.

THE VISUAL GAGE is an indicating comparator set by means of precision gage blocks for checking external dimensions, the angularity of surfaces, the angularity between a bore and a surface, run-out, and the pitch diameter of screw threads. It is both a production and a tool room instrument. Write for catalog.

STANDARD GAGES

Sheffield can supply any type of standard or fixed size gage and a wide range of indicator gages for shop checking.

the Sheffield corporation

Dayton 1, Ohio ***U. S. A.***

Gages, Measuring Instruments, Machine Tools, Contract Services and Threading Tools.

Hope to see you at the ASTE Show, Booth 830.

INDUSTRIAL QUALITY CONTROL
Published Bi-monthly
by the
AMERICAN SOCIETY FOR QUALITY CONTROL
Inc.
305 East 43rd Street
New York 17, N. Y.

George D. Edwards, President;
Bell Telephone Laboratories
New York, N. Y.

Frederick J. Halton, Jr., Vice President;
Deere & Co., Chicago, Ill.

Ralph E. Wareham, Executive Secretary;
National Photocolor Corporation
New York, N. Y.

Alfred L. Davis, Treasurer;
Rochester Institute of Technology
Rochester, N. Y.

Advisory Council

Dr. E. U. Condon
Director, Bureau of Standards,
United States Department of Commerce
Washington, D. C.

Mr. M. Herbert Eisenhart
President, Bausch & Lomb Optical Co.
Rochester, New York

Brig. Gen. Hermon F. Safford
Executive Vice Pres.,
Ohio Rubber Co.
Willoughby, Ohio

Dr. Walter A. Shewhart
Member, Technical Staff
Bell Telephone Laboratories, Inc.
Murray Hill, New Jersey

Mr. Charles D. Wiman
President, Deere & Co.
Chicago, Illinois

Editorial Board

Mason E. Wescott, Chairman
Martin A .Brumbaugh
Irving W. Burr
Cecil C. Craig
Harold F. Dodge
Churchill Eisenhart
Joseph M. Juran
Lloyd A. Knowler
Frederick Mosteller
Edwin G. Olds
Ellis R. Ott
William B. Rice
Leslie E. Simon
A. E. R. Westman

* * *

Copyrighted 1947
by the
AMERICAN SOCIETY FOR QUALITY CONTROL
Inc.
Printed in U.S.A.
All rights reserved

Neither this magazine nor any portion thereof may be copied or otherwise reproduced without written permission of the copyright owner.

Permission for reproduction of certain specific portions of the contents may be given upon request, with the understanding that due source credit will be accorded.

Statements and opinions given in articles and papers appearing in INDUSTRIAL QUALITY CONTROL are the expressions of contributors for which the Society assumes no responsibility.

Correspondence is invited on all controversial matters.

General Information

INDUSTRIAL QUALITY CONTROL is published in January, March, May, July, September, and November, and is mailed to all members of the Society as one of the privileges of membership.

Direct Subscriptions to INDUSTRIAL QUALITY CONTROL will not be accepted from individuals. However, subscriptions to the magazine will be received from Libraries and like institutions at five dollars per year. Remittances must be in United States funds and should be sent directly to the Treasurer of the Society.

Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $5.00; for Senior Members, $10.00; for Fellows, $15.00. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

Membership in the Society is personal and professional, and is not open to corporations, companies, or other organizations.

Contributions to the Society for the support of its activities will be accepted from corporations, companies, and others.

Advertising space in INDUSTRIAL QUALITY CONTROL is available.

Correspondence concerning membership, dues, and allied matters should be addressed to

Ralph E. Wareham
Executive Secretary
305 E. 43rd St.
New York 17, N. Y.

Correspondence concerning institutional subscriptions, other financial matters, and requests for back issues should be addressed to

Alfred L. Davis, Treasurer ASQC,
Rochester Institute of Technology
Rochester 8, N. Y.

Make checks payable to:
American Society for Quality Control.

Inquiries regarding advertising rates, advertising contracts, and advertising space available should be addressed to

Edward D. Thompson
American Society for Quality Control
Post Office Box 1097
Chicago 90, Illinois

Editorial correspondence and requests for copyright releases should be addressed to

Mason E. Wescott
Chairman, Editorial Board
Lunt Hall, Northwestern University
Evanston, Illinois

Cost of Back Issues

Most back issues can still be supplied individually at $1.00 each, but certain issues are now available only in complete volumes at $5.00 each. Volume I includes the six issues from July, 1944 through May, 1945. Volume II includes the six issues from July, 1945 through May, 1946. Volume III includes the six issues from July, 1946 through May, 1947

VISIT BOOTH No. 302
The Tool Engineer's
Industrial Exposition

STANDARD

DuBo*

The plug gage that is replacing cylindrical types

*Patents Pending

LIGHTNESS in weight, ease of handling, and definiteness of indication are giving DuBo preference among machine operators, inspection personnel and engineers.

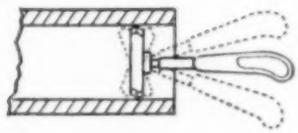
Only 1/5 as heavy as equivalent cylindrical plug gages

Readily entered — even into undersize bores

Easily detects taper and out-of-roundness

Checks ordinary bores better and quicker than cylindrical plugs

Does a variety of jobs cylindrical plugs can't do



Operates by tilting handle. Whether handle will drop freely or not is the definite, yes-or-no indication.

GAGING SURFACE (Spherical)

DOUBLE END
Size 1.510" (38mm.)
and smaller

SINGLE END
Size 1.510" (38mm.)
and larger

WRITE FOR BULLETIN

STANDARD GAGE CO., Inc., Poughkeepsie, N.Y.

AIEE MONOGRAPH STATISTICAL METHODS IN QUALITY CONTROL

During the period from May 1945 to October 1946, the American Institute of Electrical Engineers published, in its magazine Electrical Engineering, a series of ten short articles on the basic principles of quality control. Most of the articles required little more than a page each. The longest was three pages.

Demand for reprints of these articles has been so great that they have been collected in the form of a monograph which is available at $0.35 per copy to AIEE members and $0.70 per copy to non-members. Orders should be addressed to

American Institute of Electrical Engineers
33 West 39th Street
New York 18, N. Y.

Included on the AIEE Committee which supervised preparation and publication of the articles were:

H. F. Dodge, Fel. ASQC.
E. E. Folsom, Sen. Mem. ASQC.
R. E Wareham, Fel. ASQC.

NOTES

1. The Post Office Department does not forward IQC to forwarding address. The magazine is delivered to the address on file with the Executive Secretary. If you make a change of address and expect to get your copy of IQC, see that prompt notice of the new address is sent to

   Ralph E. Wareham
   Executive Secretary
   305 E. 43rd Street
   New York 17, N. Y.

2. Contributors to IQC can help greatly with the mechanics of processing and publishing their manuscripts if they observe the following rules.
   (a) Submit a minimum of two copies of the paper, each typewritten and **double-spaced.**
   (b) Submit at least one set of charts, graphs, and diagrams with all data, lettering, and art work in black India ink on a good grade of non-transparent paper.

Industrial Quality Control

VOL. IV MARCH, 1948 No. 5

Table of Contents

	Page
AIEE Monograph	5
Notes	5
The Technique of Experimenting in the Factory — Leonard A. Seder	6
Report of Second Annual Convention, ASQC, and Fourth Annual Rochester Society Quality Control Clinic	
Luncheon Session — 16th February	14
First General Session — 16th February	15
Convention Dinner — 16th February	15
Convention Pictures	16
Second General Session — 17th February	18
Luncheon Meeting — 17th February	19
Clinical Sessions — 17th February	19
Analysis of Variance — B. A. Griffith, A. E. R. Westman, B. H. Lloyd	20
American Society News	
Annual Meeting	26
Recognition of Sections	26
Code of Ethics Adopted	26
Dr. Shewhart Honored	26
St. Louis Section Makes Sustaining Contribution	26
Standing Committees	26
General Committees	26
Joint AIEE-ASQC Activities	27
New Information Folder and Application Blank	27
Membership Renewals and New Members for 1947-1948	27
Transfers to Senior Memberships	27
Transfers to Fellowship	28
Book Review	28
Forthcoming Lectures and Courses in Statistical Quality Control	
Lectures in Industrial Statistics — MIT	29
Ten-Day Course — University of Illinois	30
Eight-Day Course for Chemical Industries — RIT	30
Eight-Day Advanced Course — Purdue University	30
Classified Ads	
Consulting Services	31
Positions Wanted	31
Positions Available	31

The Technique of Experimenting in the Factory*

LEONARD A. SEDER

QUALITY CONTROL ENGINEER, GILLETTE SAFETY RAZOR COMPANY

Every factory has its Chief Trouble-Shooter. Sometimes he is the foreman on the job, sometimes the chief inspector, the superintendent, or again the process engineer. Whatever his title, to him falls the job of pressing the right buttons to keep the job humming in a quality sense. Intimate familiarity with the process, ingenuity, detective ability, and horse sense are usually the chief tools in his kit. Frequently, however, the issues are so important that he cannot rely solely on these but must resort to "making an experiment" to let the facts "speak for themselves."

Unfortunately, "facts" thus obtained often speak double-talk. What is a sound conclusion today fails to stand up tomorrow. "Something else must have changed" is the usual disposition of the matter after much head-scratching. What to do with all the "something elses" that constantly get in the way of permitting a straightforward conclusion to an experiment is not always a simple problem.

Lately, two new tools for effectively dealing with "extraneous" influences have been developed. One is the **concept of variation** embodied in the viewpoint of statistical quality control and the other, its twin sister, is **analysis of variance.** Much has been written to explain the former in layman language, but little is available on the latter, possibly because of its inherently mathematical nature.

Statistical methods in the design and analysis of experiments have a great contribution to make to industrial thinking. There is so much to be learned from the cold, sheer logic implicit in the design of such experiments that vast improvements in experimental technique can be made from a study of the design factor alone, quite aside from the statistical methods. It is the purpose of this article, therefore, to show how those who would experiment on industrial processes can profitably take a leaf from the book of the statistician, even though they eschew his statistical methods. In brief, it is an effort to bridge the wide gap between the limitedly practiced experimental technique employing statistical analysis and the much more prevalent hit-or-miss methods.

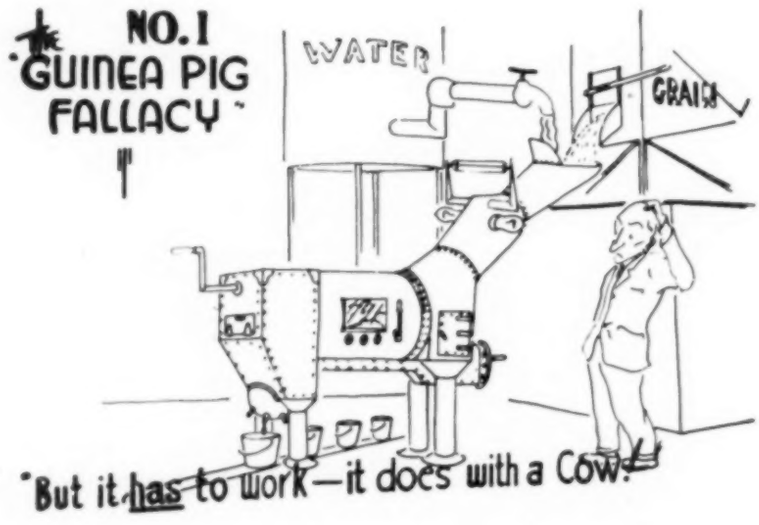
The inadequacies of present methods are best shown by an examination of some of the typical fallacies of reasoning suffered by those who lack a clear picture of the **concept of variation.**

THE GUINEA PIG FALLACY

The first is what Paul Peach† has called the "guinea pig" fallacy, so-called because it used to occur in medical research as: "because it is true of guinea pigs, **therefore** it is true of human beings." It is the fallacy of inducing too general a truth from too limited an amount of data or of extending an induction from one set of circumstances to an entirely new set of circumstances, under which it is not, per se, applicable. This type of fallacious reasoning is so much a part of almost everyone's daily thinking that it requires a conscious effort to overcome it. We judge a new acquaintance by a few chance remarks or even merely by his background. Bitter personal controversies result from too hasty inductions from a few bits of evidence and, even more regrettable, from deliberate omission of evidence which fails to support the induction. People believe generalities which they want to believe. "The wish is father to the thought," as it is said.

*Presented at a joint meeting of the Metropolitan Sections of ASME and ASQC, February 20, 1948.

†"The Use of Statistics in the Design of Experiments," *Industrial Quality Control*, November, 1946.



A certain shoe manufacturer once tested some samples of a particular plastic material for use in place of upper leather. So poorly did the sample stand up that the executive concluded that plastics were unsuited for such use. Events since have proved his error. An engineer of the author's acquaintance performed life tests on some pilot-plant samples of a new type of rectifier and published the results, indicating that they were typical of the product's performance. Much to his chagrin, he has never been able to obtain the same results on production samples. An inspection supervisor used to "spot-check" his employees' work daily by sampling from the top tray of the day's skidload as it left his department. Somehow, his results always were at odds with what the assembly department found later. He finally discovered that the routine of picking up the inspectors' work practically guaranteed that the top tray would always be the work of the same operator, who happened to be a very good one.

The cure for the "guinea pig" fallacy is to broaden the base of the experiment. Include those variables which, in the normal production cycle, must be "lived with." Include more than one operator, more than one machine, more than one batch of material. In short, make the experiment as truly representative of the production conditions as possible, yet in such a way that the effect of these "extraneous" variables can be evaluated when the experiment is completed. That this can easily be done will be indicated presently.

THE RABBIT'S FOOT FALLACY

The second type of fallacy commonly found in industrial experimentation is the "rabbit's foot" fallacy. The implication of the rabbit's foot is that a particular piece of good luck befell its owner **because** he rubbed the poor deceased animal's pedal extremity. It is the fallacy of **false cause** or associating an effect with a cause with which it is not, in truth, associated.

Here is one typical example. Trouble in knurling certain brass rod seemed to be associated with a particular vendor's material. At the same time, it was noted that the

hardnesses of certain of this vendor's lots were over the specification. Hardness was assumed to be responsible for the poor knurling, and the questionable lots were rejected on the vendor. Shortly thereafter, the knurling operation was shut down for some time, although raw material from the vendor (now within the proper hardness range) continued to pour into the plant, and thence to storage.

When the knurling operation was started up again, the trouble was still evident on the material with satisfactory hardness. The answer proved to be in the metallurgical structure, which was discovered after a well designed experiment covering vendors, hardnesses, and knurling machine variables showed that the stock was definitely inferior. But the "rabbit's foot" had done its work and thousands of dollars were sacrificed because the hardness hypothesis was allowed to become a conclusion without being tested.

Perhaps the most common industrial case of this fallacy is the theory that an innovation in material or processing can be evaluated by substituting it for the standard method in production for "a day or two." The experimenter is supposed to be able to conclude that, **because** the quality of product was better (or worse) that day, it was the **result** of the innovation.

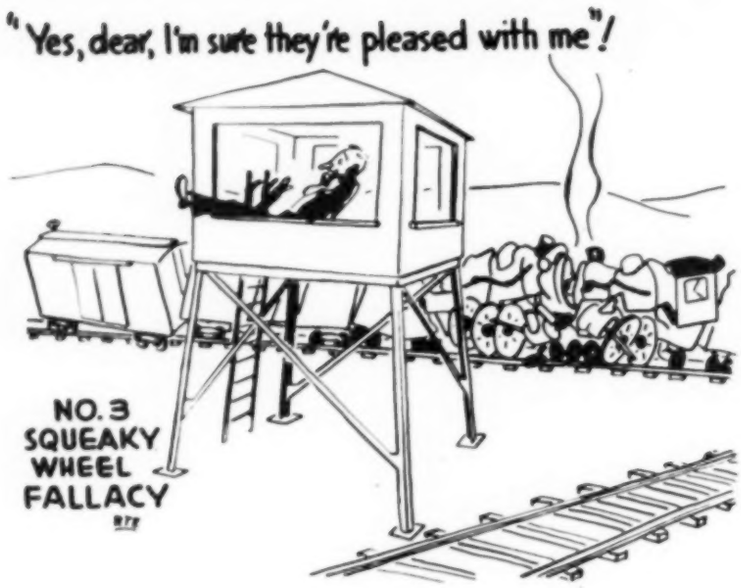
This is a highly dangerous procedure because of the dynamic nature of the industrial process, which has a whole universe of things that vary with time. Raw materials change, operating personnel changes, gages wear, instruments shift in calibration, alterations (intended and otherwise) are made in instructions, processing methods are improved. One must visualize this galaxy in constant motion, changing ever so slightly from day to day, but presenting as different an appearance six months from now as does the night sky in its seasonal movements. Superimposed on this basic appearance are the daily weather conditions—the day-to-day variations—which also alter the appearance of our industrial "sky." The mere fact that a particular constellation is not visible on a particular night is not evidence that its course has been shifted. A localized weather condition may be responsible. The experimenter must constantly ask himself whether the sky's face has really had plastic surgery or is merely wearing a mask.

Too many times, when innovations are hurriedly tried, localized effects are mistaken for basic ones; and the experimenter is off to another false start. He is guilty of assuming that one thing has **caused** another thing merely because the second **follows** the first in point of time.

The surest cure for the "rabbit's foot" fallacy is to demand that the experiment have an adequate "control." It will be recalled that Pasteur had to resist the impulse to inoculate all the anthrax cases with his vaccine so that he would have a controlled group **which did not receive the treatment.** In the

knurling problem cited, a comparison of the knurlability of the material of both hardnesses would have provided the control and would have quickly indicated that hardness was not the answer. If a new method of processing is to be evaluated, it should be run in parallel with the standard on the same lots of product. If a new material is to be tested, it should be compared with the standard material run through the identical setup at the same time. Errors or variations should not be depended on to "cancel each other" unless a positive effort is made to see that they really do distribute themselves uniformly.

Another way to steer clear of this fallacy is to suspiciously regard any conclusion purporting to show the cause of a particular effect when the argument is based mainly on the fact that the effect **followed** the supposed cause in terms of time.



THE SQUEAKY WHEEL FALLACY

A third type of fallacy frequently encountered in industrial thinking is the "squeaky wheel." It operates on the principle that the "squeaky wheel gets the grease." If something is wrong with a conclusion, it will "squeak." It says: "If we do not hear any complaints from the foreman, we can assume this new material is O.K.". It is the philosophy of negativism.

There are many more would-be experimenters using this philosophy than their superiors would like to believe. They are the purchasing agents who change vendors without confirmation of the department using the material. They are the engineers who change manufacturing instructions without consulting the operating departments involved; they are the inspector who take liberties with the interpretation of the specifications; they are the operators who pass the bad work along anyway; they are even the superintendents who issue edicts without consulting their subordinates. All depend on being able to conclude that their decisions are right if they do not receive any complaints.

In experimental work, this fallacy arises when decisions are based on the absence of contrary evidence rather than the presence of positive supporting evidence. Often, these decisions are the seemingly unimportant ones relative to the design and method of conducting the experiment. Shall raw material be included as a variable in this test? There is no evidence to show that it is an important variable. Yet, if this fact alone is used as a basis for deciding to omit it, a higher risk is taken that the experiment will fail in its primary purpose of showing the causes of variable quality.

The following story has probably been repeated countless times in hundreds of plants. A customer's complaint made it necessary to run some life tests on an electrical gadget with two types of protective finishes. Samples of the product were taken by the laboratory from the production line, given the two types of finishes and exposed to various accelerated weathering and exposure tests. When the tests were completed in three weeks and presented to the product engineer, he immediately pointed out that the test was worthless since none of the samples were originally within the specification. In the hurry to start the test, the experimenter had scooped the samples from the line without waiting for routine inspection. He had assumed they were representative samples because no evidence to the contrary existed. He erred in failing to prove their worthiness by a positive check.

The cure for this fallacy is, of course, to avoid decisions which are based on the **lack** of evidence. An investigation into the facts should be made and positive evidence obtained. Francis Bacon had the answer to this when he wrote: "If a man will begin with certainties, he shall end in doubts; but, if he will be content to begin in doubts, he will end in certainties."

To summarize this criticism of present-day industrial experimenting three recommendations have been made:

(1) The experiment must be broad enough to enable the experimenter to draw as general a conclusion as he hopes to make.

(2) The experiment must have a "control."

(3) Decisions relative to the experiment should be based on the presence of positive supporting evidence rather than the lack of contrary evidence.

THE DEDUCTIVE METHOD

In addition to their tendencies toward fallacies in thought, there are additional reasons—from the standpoint of pure logic—why the generally practiced experimental methods fail to solve many of industry's quality problems. These are best illustrated by an examination of the usual thinking patterns of an experimenter seeking to el-

iminate a quality disturbance. One is the straight deductive approach.

A screw machine operator observes that the work from a particular machine has poor surface finish. He has an unsatisfactory result. To explain the result, he must find a cause. He arrives at a tentative cause by **deduction**, in the manner made famous by Sherlock Holmes. He knows that dull tools produce poor surface finish (major premise). He presumes that this tool is dull (minor premise) and that, therefore, it is producing poor appearing parts (conclusion).

He then removes the tool and sharpens it, basing his action on the converse premise that sharp tools produce good finish. If this fails to correct the fault, the entire mental process is repeated and a new "cause" deduced. Since there are many other possible causes of poor finish, he may have to repeat the process several times before the disturbance is removed.

It is a fundamental characteristic of the deductive method that the experimenter **first** attempts to explain the result and **second** to test the explanation. Even the great Holmes often found it necessary to confront the suspect with his deductions to ascertain their validity.

In the type of fairly simple problem cited above, the deductive method can be used successfully. Most automobile mechanics, radio repair men and, in fact, anyone admiringly referred to as a "practical" man will be found to rely almost wholly on this type of attack. Some call it the "trial and error" method; others, less charitable, call it "diddling." It is most successful when the applicable major premises are well-established general truths well-known to the experimenter and where the time and expense of the "process of elimination" are not significant factors.

It is least successful in a wide area of industrial experimentation where the general laws governing the process are not well-understood and where expensive, drawn-out experimenting cannot be afforded.

THE INDUCTIVE METHOD

A second thinking pattern is the simple inductive approach. Instead of assuming a general law and deducing a correction, the experimenter seeks to prove the existence of a general law or to show that a known general law is applicable to the problem at hand. The procedure of the experiment becomes **first** to gather facts, **then** to explain them, instead of the reverse.

Here is an example: The operator of a plastics molding press observes that some of his pieces are short because of insufficient filling of the mold. To determine whether temperature is responsible, he produces parts at each of several temperatures and carefully observes the results. He may find, for example, that the pieces are charred above 300°, are short below 275°, but are satisfactory within the 275°-300° range. He has thus learned specifically how the known "general law" of temperature-plasticity and temperature-oxidation applies to the case at hand. If temperature does not produce the desired effect, he may have to repeat the procedure with injection pressure, material feed rate, nozzle size, etc.

In such a fairly simple case, the immediate aim of the inductive method is not the correction of the trouble but the deliberate synthesis or reproduction of the undesired conditions by control of the cause. When it is shown that the effect can be created at will by turning on and off the assumed cause, it is concluded that the "general law" or "cause system" affecting the product has been properly induced. The corrective action needed may or may not be obvious from the simple inductive experiment.

This is the traditional method widely practiced in scientific research. Its fundamental assumption is that everything else can be held constant while the factor under study is varied. Frequently this condition is actually met in the laboratory (although less so than is generally supposed). Rarely, if ever, does it happen in an industrial process. Thus the purely inductive experimenter is led into an insoluble dilemma. He must do either one of two things:

(1) Create a highly artificial environment in which to run the experiment. This leaves him open to committing the guinea pig fallacy when he attempts to generalize the results, or

(2) Test the hypothesis in the presence of the production variables. Then he is in danger of the rabbit's foot fallacy since he will never be sure whether the result obtained was produced by the consciously varied cause or by the many other possible causes.

The purely inductive approach, then, is also limited in use to simple cases. Like the deductive method, its efficiency depends on how quickly the experimenter can spot the correct hypothesis to examine.

THE DEDUCTIVE-INDUCTIVE METHOD

The most useful method is derived by combining features of both types, as follows:

(1) By careful examination of all of the available information (sometimes with the assistance of simple preliminary experiments), the experimenter proceeds to **deduce** all the possible causes for the observed effect. Broadly speaking, these will be found within the categories of Men, Machine, Material, and Method.

(2) He then designs an **inductive** experiment in which the samples are so arranged with respect to one another that all of the possible "causes" are contained in a single coordinated plan.

(3) Upon completion of the experiment, he is able to analyze the results to determine how much, if any, of the observed quality defect was contributed by each of the "causes."

This approach has the obvious virtue that, since all of the "causes" were present and acted on the samples in a known way, the inapplicable "causes" will be discarded with finality and the applicable ones selected with confidence. In the use of this technique, the entire viewpoint of the experiment may be shifted. The primary

objective may no longer merely be to spot and correct the present ailment, but to draw an outline of the main cause systems affecting the quality of the product so that both present and future maladies can be diagnosed.

Those familiar with statistical methods of design and analysis will readily agree that this is the most effective and most efficient method of experimentation. Much of the same general philosophy, however, can be applied without the use of statistics. A brief consideration of the fundamental design factors of the statistically-conceived experiment will be necessary to show how this can be accomplished.

DESIGN FACTORS

Having at hand the list of all possible variables conceivably capable of producing the effect under examination, the experimenter's first step is to decide in each case whether the variable will be **standardized, randomized,** or **deliberately varied.**

To **standardize** a variable is to limit it to one and only one value or item for all samples of the experiment. The advantage of standardizing a variable is that it keeps down the magnitude of the experiment; it means one less factor to contend with. By the same token, however, the experiment becomes incapable of shedding any light on the effect of that variable. In the event that it is one of the many unsuspected causes of variation, this may be a serious loss. Moreover, when a variable is standardized, one is prone to commit the "guinea pig" fallacy and attempt unjustifiably to extend the results of the experiment to other values of this variable.

To **randomize** a variable is to permit each of the samples of the experiment an equal chance of having any particular value of the randomized variable associated with it. The advantage of randomizing is that it prevents confounding of the experiment. (e.g., if one lot of material is used on one machine and a second lot on another machine, it will be impossible to state whether the result is characteristic of the material or the machine—the experiment is confounded. One way of randomizing would be to thoroughly mix the two lots of material and select the two machine samples at random from the mixture.)

The disadvantage of randomizing is that it pools one more variable into the "experimental error" —which is defined for present purposes as the differences between samples treated identically. (e.g., if, in the above, the two lots of material are, in fact, different, then the variation between samples of the mixture done on the same machine will be larger than it would be on a single lot of the material).

To **deliberately vary** a variable is to include it as one of the earmarked factors of the experiment, using different values on successive samples. The disadvantages of both standardizing and randomizing are simultaneously overcome by so doing, for the experiment will shed light on the effect of the variable and the "experimental error" will be kept to a minimum value. (e.g., in the above example, each material would be run in each machine, and thus we would learn the effects of both machines and materials **and** we would gain back what loss of sensitivity accompanied randomizing).

The disadvantage of deliberate variation would seem to be that inclusion of another variable has made the experiment more complicated, more difficult to perform. In a sense this is true, viz, the initial experiment may be more involved than the initial experiment by traditional methods. However, in this case, the initial experiment is likely to be the final experiment, whereas in the traditional scheme, it is likely to be but the first in a long series of overlapping, inconclusive meanderings.

COMPARISON OF TECHNIQUES

It is in the decision as to which of these three treatments shall be given to each variable that the basic distinction is seen between the traditional and statistical experiments. The "modern" technique using the statistical design principles without the statistics will also be examined in this respect to illustrate its middle-of-the-road position. (See Figure 4. The "variables" referred to in this figure might be: ♯1—Machine, ♯2—Raw Material Vendor, ♯3—Operator, ♯4—Cutting Speed, ♯5—Feed).

In the **traditional** method, all variables except the one under consideration are standardized. As previously explained, this frequently leads to the fallacies already discussed.

In the **modern** method, some variables are standardized, some randomized, and some deliberately varied. Those which are **standardized** are of two types, i.e., when it is physically impossible to do otherwise or when strong engineering conviction exists that the variable has no effect on the quality characteristic being studied. Two or

FIGURE 4—COMPARISON OF THREE METHODS

three or even more variables can be **deliberately varied.** These will be the ones which are suspected of having an effect and, in general, those about which something can be done in a production sense. Finally — and herein is the core of the method — all other variables are **randomized.** In general, those to be randomized are those difficult or undesirable to standardize because they are bound up with the production operation. Examples: the position of a particular sample in a multi-position machine, the operator (when there are several doing the same work), the particular machine (when several are run in parallel), or the particular lot of raw or partly processed material.

(Note that these variables are randomized when they are **not** the chief variables under study. It is easily conceivable that they might be, in which case they are among the deliberately varied group).

In the **statistical** method, the scheme is identical with the modern, except that a greater number of variables can be varied simultaneously, and thus some of those which were randomized in the modern are **deliberately varied** in the statistical.

EXAMPLES OF MODERN DESIGN

Two examples will now be cited to indicate the applicability of this modern design. The first example will show the simplification possible, and the greater value realized, as compared with the traditional. The second example will show an actual application of the modern method in studying a visual defect condition.

For the first example, suppose that varying quality results have been experienced with a chemical etching process on some aluminum parts. It is desired to study the process and smooth it out by recommending any necessary changes in equipment or procedure. After a preliminary survey, it has been decided that there are four major variables which conceivably could influence the variability of the process. These are:

(1) Temperature of the etching tank.
(2) The particular tank used. (There are four.)
(3) Variation in lots of raw material.
(4) Time of immersion of the parts.

LOT "A" TANK NO. 1

TIME \ TEMPERATURE	50°	60°	70°	80°
10 min.	10 min.	10 min.	10 min.	10 min.
20 min.	20 min.	20 min.	20 min.	20 min.
30 min.	30 min.	30 min.	30 min.	30 min.
40 min.	40 min.	40 min.	40 min.	40 min.

FIGURE 5—TRADITIONAL

LOT "A-B-C-D"

TIME \ TEMPERATURE	50°	60°	70°	80°
10 min.	TANK NO. 1	TANK NO. 2	TANK NO. 3	TANK NO. 4
20 min.	" NO. 4	" NO. 3	" NO. 2	" NO. 1
30 min.	" NO. 3	" NO. 4	" NO. 1	" NO. 2
40 min.	" NO. 2	" NO. 1	" NO. 4	" NO. 3

FIGURE 6—MODERN

THE TRADITIONAL APPROACH

The strictly traditional inductive approach (see Figure 5) would probably be as follows:

(1) Standardize on one tank and one lot of raw material.
(2) Make time-temperature runs at each of about four different temperatures.
(3) Repeat each run a second time to see how closely they check.

Assuming four times and four temperatures, this means a total of 32 sets of samples to be tested. (One set of samples might be perhaps 5 aluminum pieces). The experimenter will undoubtedly get some information on the effect of time and temperature, but will it apply to the next lot of material or to another tank? He does not know, and so he may have to repeat the entire procedure with each of three more lots of material in the same tank. Now he will have tested 128 sets of samples. He still needs to know the effect of tanks, so he repeats the experiment again, this time using all four tanks with one lot of material. This makes 224 tests. He ought to be getting a fair idea of which variables influence the result. (Note that he has not made all the possible combinations, however. If a double run were to be made with each material on

each tank, it would require the astounding total of 512 sets of samples).

THE MODERN APPROACH

The modern technique (see Figure 6) would be applied as follows:

(1) Randomize raw materials. Mix all four lots of material until they are homogeneous, and draw out samples at random.

(2) Randomize tanks. Use the different tanks in a predetermined order in such a way that the effect of tanks cannot be confounded with any other variable.

(3) Under these conditions, make a time-temperature run at each of four temperatures.

This procedure requires 16 sets of samples. The data thus obtained will be realistic. It may not be as sharply focusing on a particular time and temperature as were the first 32 tests in the previous methods, but it will tell the range of time and temperature likely to be satisfactory with the normal amount of material variation and the four pieces of existing equipment.

If, on the other hand, it should turn out that tanks or materials are the real controlling variables and time and temperature make little difference, it will be apparent in that the variability of samples treated identically (i.e. at the same time and temperature) will be excessive compared with the effect of time and temperature. It will then be necessary to run a second experiment, now standardizing time and temperature, and deliberately varying materials and tanks.

THE STATISTICAL APPROACH

The statistical design (see Figure 7) is very similar to the modern, except that raw material is now included in the purposely varied group instead of being randomized. Tanks are used in the same way as in the modern, but the statistician will be able to separately analyze the effect of tanks. Thus the possible need for a second experiment is virtually eliminated. This method also uses only 16 sets of samples and, when the analysis has been completed, it will be easy to decide which variables need finer control in production or must be studied further, and which variables can be eliminated as having no effect.

TIME	TEMPERATURE 50°	60°	70°	80°
10 min.	TANK NO. 1 LOT A	TANK NO. 2 LOT B	TANK NO. 3 LOT C	TANK NO. 4 LOT D
20 min.	NO. 4 B	NO. 3 A	NO. 2 D	NO. 1 C
30 min.	NO. 3 D	NO. 4 C	NO. 1 B	NO. 2 A
40 min.	NO. 2 C	NO. 1 D	NO. 4 A	NO. 3 B

FIGURE 7—STATISTICAL

A CASE IN POINT

An actual case in which modern design was successfully applied without the need for statistics will now be cited. A factory had experienced difficulty in hot-pressing a resin-coated paper to a metal sheet. The method consisted simply in placing the paper and metal in contact between electrically-heated platens and exerting pressure with a jackscrew. After cooling, many of the papers lifted or "blistered." While good adhesion was required, no appreciable flow of the resinous material could be permitted, since the paper was punched with 188 tiny holes which could not be allowed to fill with resin.

Four possible causes were considered likely to have been operative:

(1) Excessive temperature variation in the platens.

(2) Insufficient resin on some of the paper.

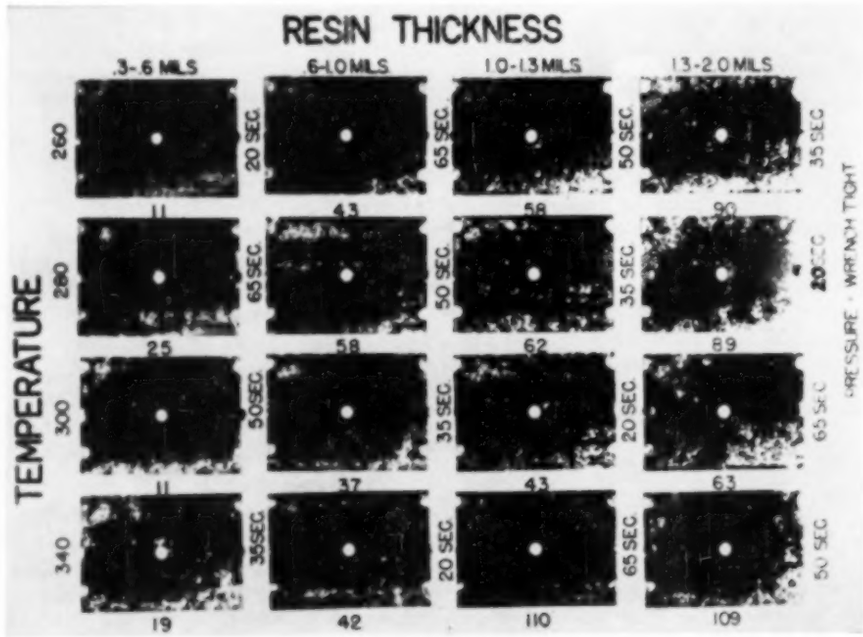


FIGURE 8 — ADHESION AND SQUEEZE-OUT — TEST NO. 1

(3) Insufficient time allowed for full adhesion.

(4) Excessive pressure variation because of the hand method.

Accordingly, an experiment was designed to test the first three of these variables. (Better engineering judgment would have included the fourth, as will be apparent). Pressure was standardized by providing a torque-wrench, and the other three variables were varied in a manner similar to that shown in the previous example. The results are shown in Figure 8. The rectangular pieces are the metal plates, with the paper stripped off to reveal the extent of adhesion. (Light areas indicate poor adhesion). The numbers under each plate are observations of the number of holes plugged up by resin flow out of the total of 188 per plate. (Known as the "squeeze-out").

It was apparent from these samples that:

(1) Time and temperature, within the range studied, were without appreciable effect on either adhesion or squeeze-out.

(2) Resin thickness decidedly affected squeeze-out, but not the adhesion.

(3) Pressure was probably the important factor on adhesion. This inference was drawn from the fact that the pattern was the same in all samples, which could be easily explained if the pressure was not being uniformly distributed over the surface of the platen.

The experimenter was not content with obtaining merely an inference, however, and therefore he quickly set up another experiment to actually demonstrate the pressure effect and, at the same time, made efforts to smooth out the pressure distribution by placing lead sheets on the platens on some of the samples.

The pressure effect was then clearly demonstrated, as shown in Figure 9. Those with only hand or contact pressure show practically no adhesion, while the higher pressure shows good adhesion.

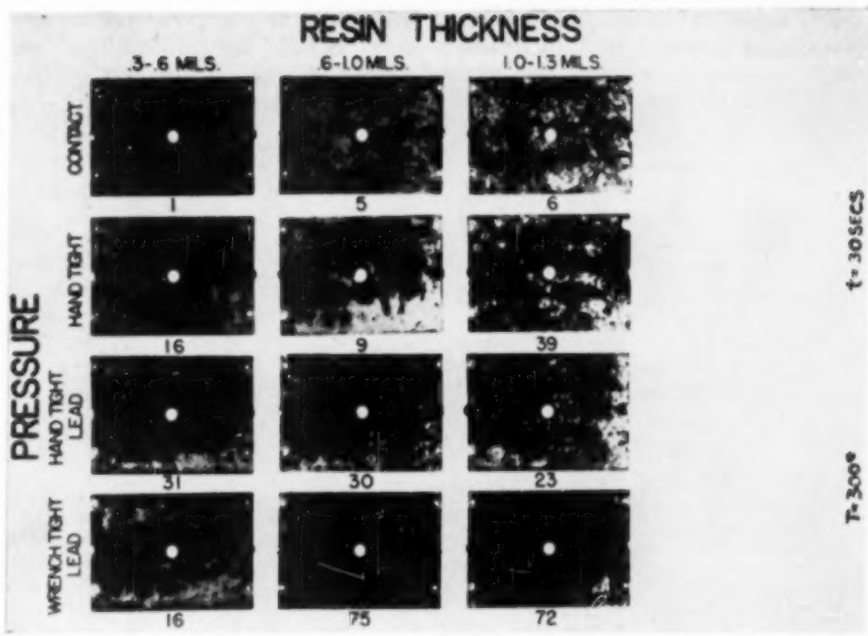


FIGURE 9 — ADHESION AND SQUEEZE-OUT — TEST NO. 2

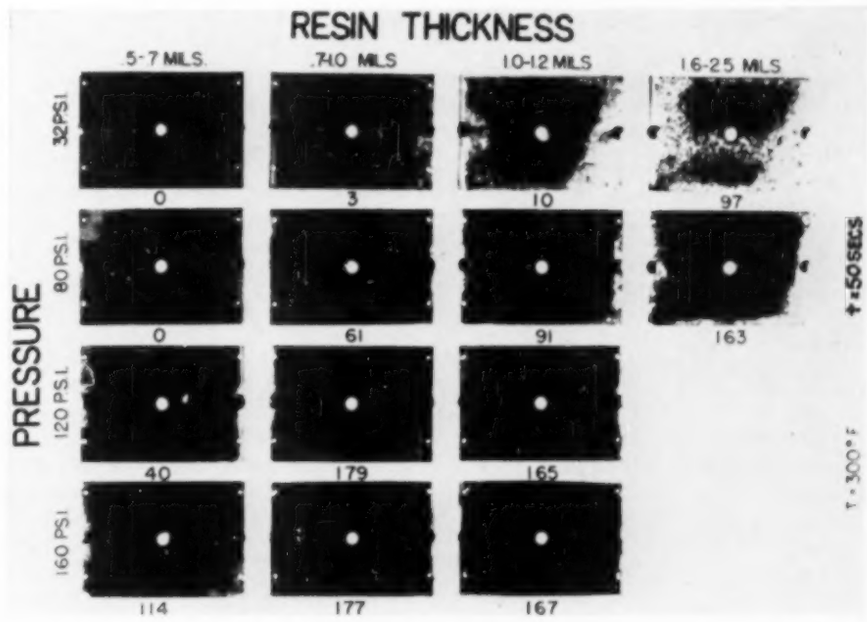


FIGURE 10 — ADHESION AND SQUEEZE-OUT — TEST NO. 3

(Note that time and temperature could now be standardized, having been already ruled out on the first experiment).

Since pressure was the important effect, it was necessary to design a third experiment in which measured pressures were employed in order to have precise data for correction. Also, a better method of distributing pressure was found in the use of heat-resisting neoprene sheeting. Figure 10 shows the results of the third test. Here much improved adhesion is evident, and the results clearly indicate the range of pressure and resin thickness necessary to give the optimum balance between adhesion and squeeze-out, viz, a resin thickness of .5 to .7 mils and a pressure of 80 psi.

All of these experiments were completed within two days, and the results were immediately put to use as follows:

(1) Resin thickness specification was changed, and tolerances reduced. The range had previously been 1.0 to 2.0.

(2) An air pressure cylinder replaced the hand-screw method of obtaining pressure, thus providing finer and measurable control of pressure. Neoprene sheeting was used on the platens.

(3) A proposition to purchase a more expensive temperature regulator was turned down—with confidence.

(4) The time allowed for the operation was reduced by one-third.

The net effect was elimination of the trouble, reduction in cost of the operation, and restoration of the confidence of all concerned in the suitability of the apparatus for the use.

CONCLUSION

This type of experimenting "pays off" in many ways other than the solution of the immediate problem, although that in itself should be enough to justify it. The value of a well-designed experiment cannot be overestimated. It wins the respect of vendors when material problems arise. It wins the confidence of customers when complaints are answered. It is a surefire way of resolving responsibilities in the interdepartmental problems where several causes may be operative and each department seeks to avoid the onus by emphasizing the weaknesses of the other departments. A technique that does all this **can** and **should** be afforded in industry today.

REPORT OF
Second Annual Convention American Society for Quality Control
AND
Fourth Annual Quality Control Clinic Rochester Society for Quality Control

The Second Annual Convention of the American Society, held at the Chamber of Commerce in Rochester, New York, on February 16th and 17th, in conjunction with the Fourth Annual Rochester Clinic, lived up in every way to advance expectations. Over 900 persons were in attendance during these two days, some 380 of whom came from outside Rochester itself.

The general theme of "Quality Control in the Coming Buyer's Market" was effectively developed by the several speakers at the luncheon and general sessions, and by the discussion leaders at the twelve clinical sessions. Well over half the papers given at these sessions have been made available to Industrial Quality Control, and will be scheduled for publication in forthcoming issues.

As usual, the gage exhibits were an interesting feature of these meetings, as evidenced by the near-capacity crowds that visited the exhibit hall during the two-day showing. Twenty-four companies were able to take advantage of the opportunity to exhibit at this Convention.

Numerous Board and Committee meetings of the Society were held during the Convention. Attendance at these meetings was consistently good, and a number of important matters relative to the conduct of the affairs of the Society were discussed and voted on. Action taken at most of these meetings will be reported in the columns of the American Society News section of this magazine.

The Planning Committee of the Rochester Society, the Industrial Management Council of Rochester, and the Rochester Chamber of Commerce are to be congratulated for the precision and smoothness with which a very full program of activity was carried to completion, for the excellent facilities made available for the conduct of the meetings, and for the noteworthy attention to detail which served to personalize it for each registered guest. All who were fortunate enough to be able to attend these meetings had an opportunity to enjoy a stimulating program, to renew old friendships and make new ones, and to share an all round atmosphere of good fellowship.

LUNCHEON SESSION—16TH FEBRUARY

Mr. James A. Tilton, President of the Rochester Society for Quality Control, and General Chairman of the Planning Committee, presided at this first formal session of the Convention. After presenting Mr. Russel C. McCarthy, Manager of the Industrial Management Coun-

cil of Rochester, who extended official welcome to the guests of the Convention, Mr. Tilton then introduced the principal speaker, Mr. Lee McCanne, Vice-President and General Manager of the Stromberg-Carlson Company of Rochester, who addressed the audience on the subject "Management Evaluates Progress in the Quality Control Field."

Mr. McCanne pointed out that good management is always ready to welcome new ideas for improving quality. Quality control in the Shewhart sense has much to offer, but is often slow in gaining acceptance because management does not always understand how effectively it can contribute to cost reduction and the elimination of imperfections. There is a tendency to be overconservative in the matter of benefits to be expected, due partially to the fact that many general managers were formerly specialists in Sales, Costs, Engineering, or Production, but few have had any background in statistical quality control. This situation can be expected to improve as men with experience in modern quality control methods gradually move into managerial positions.

Meanwhile, quality control men should keep management informed, both of out-of-control conditions and on success stories, making available direct and simple interpretation of data that will be meaningful and pertinent at management levels.

Management recognizes that modern quality control has made, and can be expected to make, important contributions in many fields: production, engineering, employment training, vendor relations, and so on. But it must also be recognized that control charts and sampling plans do not of themselves perform miracles, and that immediate beneficial effects, which are often observed, may be temporary in nature. The search for and removal of assignable causes requires sustained and cooperative effort by competent personnel at all levels. Progress depends on sound analysis and appropriate action, not on spectacular or accidental results.

FIRST GENERAL SESSION—16TH FEBRUARY

At the first General Session, on Monday afternoon, Mr. Leonard E. Coger, Secretary-Treasurer of the Rochester Society, and Vice-Chairman of the Planning Committee, presided and introduced the speakers. The first speaker, Mr. Stuart F. Heinritz, Editor of the magazine "Purchasing," spoke on the topic "Purchasing and Quality Control."

In his talk, Mr. Heinritz outlined the essential distinctions between the natural functions of Purchasing and Quality Control departments, showed how a mutual understanding of these different functions could contribute to better operation in the interests of both quality and cost, and suggested ways for attaining closer co-operation between these departments.

Vendor-supplier relationships are fundamentally a matter of negotiation. Hence, quality-cost problems affecting these relationships should be channelled through Purchasing for negotiation. In this connection, the criterion of cost and value, not quality alone, is the standard ultimately used by management.

Every manufacturer is a supplier as well as a buyer, so Quality Control must actually consider its relations with outside purchasing departments as well as with that of its own company. Here, quality control adds to the value of a product, but the customer's purchasing agent must be convinced of this, and his conviction must be strong enough to result in purchase.

Quality of product always commands a premium. If that premium is economically justified, the manufacturer of such product may well become the preferred supplier. This should be the aim of quality control.

The second speaker at the first General Session was Mr. Philip Bowman, Vice-President in Charge of Plants, Bristol Laboratories. He spoke on the subject "Manufacturing and Quality Control."

Mr. Bowman pointed out that in making drugs, quality itself is an accepted fact, with only minor differences between manufacturers. The manufacturing problem is therefore almost exclusively that of reducing costs without impairment of quality. Hence, in connection with manufacturing in the drug industry, it is appropriate to think of statistics as "profitistics."

The penicillin industry is a $200,000,000 industry which has succeeded in reducing the cost of 100,000 units of this product from $16 to 16¢. Nevertheless, the mechanisms by which it is produced are largely unknown. There are five different kinds of penicillin, no definite specifications, methods of measurements are subject to wide variations in accuracy, in addition to the fact that the mold itself varies greatly from day to day, is unstable, particularly in solution, and is subject to large losses in the extraction process.

Mr. Bowman cited an imposing list of cost reductions and process improvements effected at Bristol Laboratories by the application of correlation, analysis of variance, control chart, and sequential sampling techniques which, in all, gave an aggregate saving of a million dollar's worth of product over a two-year period that would not have been available for sale without the successful use of these techniques. He emphasized, however, that this success story was the joint result of teamwork between the statistical and production departments, and not the sole achievement of either department alone. At Bristol Laboratories about 30% of the time of the statistical staff (three people) has been spent on applied work, the other 70% has been devoted to an educational program within the plant. As a result of these joint efforts, management has been able to lower operating costs, and feels that it need not fear competition in the coming buyer's market.

CONVENTION DINNER—16TH FEBRUARY

The Dinner Meeting was the main Convention session of the American Society. Mr. James A. Tilton opened the meeting by introducing Mr. George D. Edwards, Director of Quality Assurance, Bell Telephone Laboratories, and President of the American Society for Quality Control, who took over Chairmanship of this meeting amidst a spontaneous, rising round of applause from the audience.

STRATIFIED SAMPLE OF CONVENTION SCENES

PLANNING COMMITTEE

DR. WESTMAN
MAKES HIS POINT!

MONDAY LUNCHEON – RIGHT BOWER

MR. HEINRITZ

CONVENTION DINNER – LEFT BOWER

KERR GETS HIS DIPLOMA

QUALITY CONTROL WIDOWS

Mr. Edwards called attention to the fact that this Convention Dinner was in reality a birthday dinner for the Society, as it was just two years earlier — February 16, 1946 — that representatives of 17 local quality control societies met in New York City and organized the American Society. He reviewed accomplishments of the Society during the first two years of its existence, and discussed some of the problems that still require study and solution. Foremost among these is the problem of maintaining an active and adequate membership enrollment. On this point he spoke as follows.

"Other professional societies have learned by sad experience that their mortality rate is greatest when their membership is in the range from about 1000 to 3000. In that range, the clerical and administrative work involved in their operation is too much to expect from the voluntary effort of officers and others, even though such voluntary effort is limited to supervision and planning. Similarly, the income from dues and other sources legitimate for professional societies, is insufficient to support an organization with paid supervision of a calibre adequate to the type of operating job which we all expect.

For all intents and purposes, the American Society for Quality Control is in the middle of that critical size-range. We can't risk allowing our numbers to slip down below the lower edge of this critical range, for once really started on a down-grade, it is hard to stop. The obvious alternative is to go up over the upper edge of the range, and that is the job before us. This is a challenge which I'm sure has real appeal, and I bespeak your wholehearted loyalty and support for your future officers in meeting it."

Mr. Edwards then introduced briefly the Officers and guests of the Society who were on the dias. Among these were Mr. Donald McMaster, Vice-President and Assistant General Manager, Eastman Kodak Company, and Chairman of the Industrial Management Council of Rochester, Mr. Milton E. Loomis, Executive Vice-President of the Rochester Chamber of Commerce, and Brigadier General Herman F. Safford, Executive Vice-President, Ohio Rubber Company, and member of the Advisory Council, American Society for Quality Control.

IDENTIFICATION FOR CONVENTION PICTURES

Planning Committee — Left to right: Mildahn*, Coger, Warren, Kent, Lawrence*, Toole, Myers, Becker, Davis, Tilton, Ohl, Golemb.

Monday Luncheon — Left to right: McCanne, Toole**, Halton, Bowman.

Convention Dinner — Left to right: Bender, Winter, Brumbaugh, Wescott, Wareham.

Kerr Gets His Diploma — Left to right: Oliver, Kerr, Tilton, Davis.

Quality Control Widows — Left to right: Mrs. Wade Weaver, Mrs. Warren Jones, Mrs. Walter Oliver, Mrs. Charles Hudson, Mrs. George Edwards.

*Members of Rochester Board of Directors; not on Planning Committee.
**Assistant Manager, Industrial Management Council.

In presenting General Safford, Mr. Edwards reviewed the service which the General had rendered to the cause of quality control during the War as Chief of the Production Service Division in the Office of the Chief of Ordnance in Washington. General Safford was largely instrumental in promoting the use of Acceptance Quality Control by Ordnance, which led gradually to the introduction of Process Quality Control into the factories of Ordnance contractors. Following the Ordnance pattern, this cycle was repeated a little later in the Signal Corps, Chemical Warfare Service, Quartermaster Corps, the Navy, and the Air Force. As a result, Process Quality Control was almost forced into wide-spread use by innumerable contractors throughout the country. General Safford's support and guidance has thus contributed much to the increased use of statistical quality control during the past five or six years.

Following a brief and appropriate response from General Safford, Mr. Edwards spoke as follows.

"I mentioned a moment ago that the Army's use of Acceptance Quality Control forced industry to introduce Process Quality Control. Lack of personnel trained in quality control techniques was a major bottle-neck in both of these steps. The Army broke its bottle-neck by two series of three-day training conferences given throughout the country for something over 500 of its own personnel.

The War Production Board undertook to meet industry's need for such personnel by arranging a series of 33 intensive eight-day training courses in quality control, which were given in cooperation with some 25 colleges and universities at as many points throughout the country. During the period from 1943 to 1945, about 1850 men from war industries attended these courses.

Now the men who took these W.P.B. courses found it helpful to get together more or less frequently and compare notes and experiences, to exchange ideas, and thus to help each other. Out of these "get-togethers" came local quality control societies in some 30 cities throughout the country. A number of these local societies ceased to exist with the closing up of war industries, but at least 17 of them continued strong and healthy. And it was these 17 whose representatives organized the American Society just two years ago today.

I mention this to bring out clearly the direct way in which the American Society sprang from the W.P.B. training courses, and the fact that, had it not been for the W.P.B. courses, there would have been no ASQC today.

I had hoped that we could have with us tonight either Dr. Working of Stanford University, or Professor Olds of Carnegie Institute of Technology, or both, since both of them contributed so much, and were so largely instrumental in the success of the W.P.B. courses. Unfortunately, neither of them found it possible to be here, but we can nevertheless pay proper tribute to the debt we owe them and their many assistants and helpers on this, our anniversary."

On behalf of the American Society, Mr. Edwards expressed the gratitude of the Society to the

Rochester Section for its invitation to hold the Convention in Rochester, and to the many agencies in the city which had contributed so much to the success of the Convention, specifically, the Rochester Chamber of Commerce, the Industrial Management Council of Rochester, the City Manager of Rochester, the Rochester Convention and Publicity Bureau, and the Rochester Hotel Association.

In presenting Dr. A. E. R. Westman, Director, Department of Chemistry, Ontario Research Foundation, Toronto, Canda, as the principal speaker at the Dinner Meeting, Mr. Edwards recounted the professional record and background of the speaker which qualifies him as one of the foremost authorities in the field of industrial statistics. As a Research Chemist and Ceramist, Dr. Westman has contributed widely to the literature in ceramics, industrial chemistry, electrochemistry, physical chemistry, refractories, electric furnace arcs, paper, adhesives, printing, statistics, sampling, and quality control. He served on the committee that prepared the ASTM Manual on the Presentation of Data, first appearing in 1933, and now about to enjoy a fifth printing.

During the War, Dr. Westman was in charge of the Analytical Laboratory of the Inspection Board of the United Kingdom and Canada. He was also in charge of the installation of a quality control system for Electric Steels, Ltd., at Cap de la Madeleine, Quebec, where tank shoes, trench mortar bombs, and large shells were produced in mass quantities. He has given extension courses on quality control at the University of Toronto, and in a number of War industries near there. His notes on these courses have recently been published, and form a most valuable text-book.

Dr. Westman is a member of the American Institute of Chemical Engineers, of the Society of Glass Technology, and of the British Ceramics Society. He is a Fellow of the Canadian Institute of Chemistry, a Fellow of the American Ceramic Society, and a Fellow of the American Society for Quality Control. He is Vice-Chairman of the Committee on Quality Control of Materials of the American Society for Testing Materials, and a Member of the Editorial Board and of the Committee on Standards of the American Society for Quality Control.

Following this introduction, Dr. Westman modestly announced that he was now convinced that Bell Telephone Engineers could magnify a little squeak into a very loud noise! He then proceeded to address the audience on the subject "Quality Control Leads the Way." His paper will be published in full in the May issue of this magazine, and will be but briefly reviewed here. In his talk, he outlined simply and effectively the fundamental nature of statistical quality control, gave numerous case histories to illustrate his points relative to both process control and sampling inspection, and described some of the larger potentialities that lie ahead in the field of applied industrial statistics as the broader use of more advanced and refined techniques become available to men in experimental and industrial research work.

SECOND GENERAL SESSION—17TH FEBRUARY

Mr. Edward R. Becker, Vice-President of the Rochester Society, presided at the second General Session on Tuesday morning. He opened the meeting by introducing Mr. William Kerr, Sales Manager, Instrument Division, American Optical Company, who spoke on the subject "Sales and Quality Control."

Mr. Kerr observed that a salesman might consider quality control as an industrial product. Training and experience have provided manpower, which corresponds to manufacturing capacity. The "product" is being turned out — what we need now is a sales program for it! The talents of those sales personnel who were displaced during the war into production and quality control should be used more effectively to present the case for these newer production methods, but, in general, the sales program for quality control has not kept pace with its technical advance. If a sales department is convinced of the value of quality control, it can and should contribute its selling skill, exert influence on mangement, and aid in training quality control personnel in successful sales philosophy.

Appeals to management need not be based on cost savings alone; such factors as customer satisfaction, fewer complaints, less repairs and replacements, and so on are also convincing arguments. If a market exists, quality is the main reason for the existence of a sales department. If all competitor's products were of equal quality, only a price list would be needed. It is when better quality means a higher price that a salesman is needed to convince the customer that the product offered has the quality he needs. Continued control of high quality within limits is thus very important to the continuance of good customer relations.

Mr. Kerr also suggested ways in which statistical analysis might be used more effectively in relation to sales, and in forecasting and estimating market potentials. A buyer's market requires greater precision in these respects, and longer manufacturing cycles make it necessary to predict farther ahead. Possible fields for useful adaptation of control chart and other quality control techniques are: changes in customer preferences and reactions; study of sales distribution patterns and trends; predictions of sudden cutbacks or demands; sales quotas; territory potential; judgment of salesmen's performance; geographical preference; effect of climate; and other variables that need better and quicker evaluation than has formerly been possible.

Much can be learned from customer attitudes, many of which are never written. The salesman at the point of contact with the customer may have a different view of quality from the man on the production line. There is a real challenge for Sales and Quality Control to work together in understanding and solving their mutual relationships and responsiblities, and in preparing reports that will attract the responsive attention of management.

Following Mr. Kerr's talk, Mr. Becker introduced the second speaker, Mr. Joseph Manuele, Director of Quality Control, Westinghouse Electric Corporation, who

spoke on the subject "Engineering and Quality Control."

In his talk, Mr. Manuele effectively outlined the mutual problems and interdependence that exists between Quality Control and Engineering. He said that the link between Quality Control and Design Engineering has often been a weak one, largely because of reasons that were more psychological than fundamental.

Quality Control can do certain things to assist the design engineer. It can give an accurate report and analysis of quality at various stages, and can help in establishing realistic tolerances and specifications, so that it will not be necessary to continue to pay for unneeded operations. The design engineer should be interested in how Quality Control interprets his design, and how it is being taken by the Shop. To discharge his responsibilities most competently, he must maintain a close relationship with those who are doing the quality control job in the operating areas of the plant.

The engineer should use Quality Control in improving his design, just as the sales organization should use it as a sales factor. Design should then expect Quality Control to see that workmanship standards are upheld, and that the product is made according to the design. Likewise, the engineer expects, and should get, a true analysis of final quality shipped.

On the other hand, Quality Control should expect certain things from the engineer; for example, realistic tolerances. Terms such as "'smooth," "reduce slowly," and "room temperature" should be defined. Engineers have long worked on the principle that if you ask for .003 variation you will get .007! But Quality Control can say, "Tell us what you have to have, and we can guarantee either that you will get it or that we can show you the impossibility of what you want in terms of present equipment." Frequently, such objective cooperation between Design and Quality Control has led to revisions of tolerances that have significantly improved both the quality of product and economies of operation.

Mr. Manuele told of the case of difficulty in the production of molded parts. The engineer said the tolerance should be ±.003; the shop said the best it could do was ±.008. Quality Control showed that the range within cavities was ±.0015 and between cavities ±.017. When all cavities were made alike, it eliminated not only an inspection operation, but also a sizing and machining operation. This is a case where Design was well within attainable limits, and the Shop was wrong—Quality Control was the link that resolved the contradictions.

On the other hand, there was the case where tolerances for certain screw machine parts were specified as ±.001 or ±.0003; yet for years the parts had been made and used with variations of ±.003 or ±.004. In this case, Quality Control was the link that led ultimately to broadening of tolerances on 73 drawings covering 210 parts.

Sometimes the engineer cannot tell accurately what he needs. Then he can often get help from the data of Quality Control. In any event, the engineer is designing parts, not intermediate processes, and the Shop has to be free to use the most economical methods within the design. Hence, Quality Control and Design cannot escape mutual responsibility for quality and cost, and the closer knit the cooperation between these two departments, the better will be the end result for all concerned.

LUNCHEON MEETING—17TH FEBRUARY

Mr. Alfred L. Davis, Treasurer of the American Society, and Vice-Chairman of the Planning Committee, presided at this final General Session of the Convention. Among those on the dias at this session were the discussion leaders for each of the 12 clinical sessions held after the luncheon meeting.

The principal speaker scheduled for the luncheon session was Dr. Hugh M. Smallwood, Member of Staff, General Laboratory, United States Rubber Company. However, sudden illness had, at the last moment, prevented him from appearing to give his paper in person. After expressing the regrets of the Convention for this unfortunate circumstance, Dr. Martin A. Brumbaugh was introduced to the audience, and he very ably read Dr. Smallwood's manuscript on the subject "Quality Control in Industry During the Post-War Period."

Dr. Smallwood's paper will be published in full in the May issue of this magazine, so only a brief review will be given here. He contrasted the wartime production conditions which favored the introduction of Shewhart control techniques with the post-war situation in which considerations of cost, return to old prejudices, and producing for many purchasers instead of just one make the job of the quality control engineer a challenging one from the point of view of maintaining and extending the techniques of his profession in plant operations. Emphasis on co-operative effort, and a sustained job of effectively selling quality control to management, operating personnel, vendors, and purchasers must be kept constantly in mind by the quality control engineer if the full potentialities of a quality control program are to be achieved.

Following the reading of Dr. Smallwood's paper, Mr. Davis presented to the speakers at the second General Session, and to each of the Clinic Speakers, a certificate of acknowledgment and appreciation from the Rochester Society. (Similar presentations had been made the previous day to the speakers on that program.)

CLINICAL SESSIONS—17TH FEBRUARY

Following the Luncheon Meeting on Tuesday, twelve Clinical Sessions were held simultaneously at the Chamber of Commerce building and in rooms provided by several of the hotels. No reports on these clinical sessions, or summaries of the papers given, are available, but a number of the manuscripts will be published in full in future issues of this magazine.

CONFERENCE PAPERS

Second Annual Midwest Quality Control Conference

$3.50 Postpaid

Order from: Alfred L. Davis

Treasurer, ASQC

Rochester Institute of Technology,

Rochester 8, N. Y.

Analysis of Variance*

B. A. GRIFFITH,
DEPARTMENT OF APPLIED MATHEMATICS, UNIVERSITY OF TORONTO, TORONTO, CANADA
A. E. R. WESTMAN,
ONTARIO RESEARCH FOUNDATION, TORONTO, CANADA
B. H. LLOYD,
DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF TORONTO, FORMERLY WITH ONTARIO RESEARCH FOUNDATION

Part I—VARIANCE, THE F TEST, AND THE ANALYSIS OF VARIANCE TABLE

MEAN AND VARIANCE OF A SAMPLE AND OF A LOT**

Consider a selection of 6 articles (**individuals**) from a large group (**lot**) of such articles, and suppose that some **characteristic** (length, weight, percent carbon, etc.) of each individual is measured. We get a set of 6 numbers—the **sample values** expressed in appropriate units, e.g. 21, 22, 25, 22, 23, 22.

Summary numbers called **sample statistics**, or simply **statistics** are:

(1) a central value which gives at once some idea of the magnitude of the characteristic measured for any article. The usual choice for this central value is the arithmetic mean of the sample values, viz,

$$\overline{X} = (21 + 22 + 25 + 22 + 23 + 22)/6 = 22.5;$$

(2) a measure of variability such as the range or the standard deviation of the sample values. Another very fundamental measure of variability is the variance, or square of the standard deviation, i.e.

$$\sigma^2 = (1.5^2 + 0.5^2 + 2.5^2 + 0.5^2 + 0.5^2 + 0.5^2)/6 = (9.5)/6$$

where 1.5, 0.5, etc. are the deviations of the sample values from their respective means, the signs being omitted since they disappear on squaring.

If we could measure the characteristic in question for each individual in the lot, we would find a large set of numbers (all possible lot values) from which we could similarly calculate a mean $\overline{X}'$ and a variance $(\sigma')^2$. This is not practicable and we make estimates of the lot mean $\overline{X}'$ and the lot variance $(\sigma')^2$ as follows:

$$\overline{X}'_e = \overline{X};$$
$$(\sigma_e)^2 = (6/5)\sigma^2 = (9.5)/5 = 1.9,$$

where a subscript e indicates an estimate.

DEGREES OF FREEDOM

Let us examine the reasons for the formula $(\sigma'_e)^2 = (6/5)\sigma^2$ as our estimate of $(\sigma')^2$.

The true mean $\overline{X}'$ of the lot may differ from $\overline{X} = 22.5$; for the sake of illustration, let us suppose $\overline{X}' = 22$. The sample deviations from this true lot mean are $-1, 0, 3, 0, 1, 0$. The corresponding deviations from the sample mean are $-1.5, -0.5, 2.5, -0.5, 0.5, -0.5$, which have zero sum. The sums of squares of these deviations are 11 and 9.5, respectively. This state of affairs is typical: the sum of squares of deviations of sample values from the lot mean will nearly always exceed, and can never be less than, the sum of squares of deviations of these same sample values from the sample mean.

Now the true $(\sigma')^2$ is an average of squared deviations from the lot mean, and so is expected to exceed σ^2. The factor $6/5$ is the theoretical correction to allow for this effect.

A meaning can be attached to the correction factor $6/5$ as follows. The six sample values and their deviations from the lot mean are quite unrestricted save for the fact that they must be furnished by articles taken from the lot; in other words, the six sample values must occur among the whole set of lot values. The six sample deviations, on the other hand, must not only be allowed by the lot, but must also add to zero. Only five of the six sample deviations can take values freely from deviations allowed by the lot; the sixth must be such as to yield zero sum.

The lot variance $(\sigma')^2$ is an average of squared deviations freely allowed by the lot. But σ^2 is derived from only 5 such deviations, and theoretical considerations show that we should average using 5 as a divisor, rather than 6, to obtain an unbiased estimate of $(\sigma')^2$.

This result is general: we always estimate* lot variance from the sum of squares of sample deviations by dividing by the number of such deviations which can freely take values allowed by the lot. This number is called the number of **degrees of freedom** of the set of sample deviations. It is equal to the number of such deviations less the number of (additional) restrictions placed on them.

*Based on lectures and demonstrations presented to the Toronto Quality Control Society on April 9 and May 14, 1947, and consisting of Parts I, II and III.

**Readers accustomed to thinking in terms of population may substitute "population" for "lot" in the discussion which follows.

*Such an estimate, which is sometimes called the sample variance, is an unbiased estimate of the lot variance; its square root, however, is not an unbiased estimate of the lot standard deviation. The $\bar{\sigma}/c_2$ used in Quality Control is.

COMPARISON OF THE VARIANCE OF TWO SAMPLES. THE F TEST

Two samples of sizes 6 and 10, respectively, show sample variances of 10/6 and 27/10. The first was taken from a lot of articles manufactured by experienced workmen, the second lot was made by a group which included a number of unskilled workmen. An increase in variability in the second lot is feared.

For the variances in the respective parent lots we make the estimates

$$\begin{pmatrix}\text{variance}\\ \text{estimate,}\\ \text{first lot}\end{pmatrix} = (6/5)(10/6) = 2;$$

$$\begin{pmatrix}\text{variance}\\ \text{estimate,}\\ \text{second lot}\end{pmatrix} = (10/9)(27/10) = 3,$$

which we shall denote by e_1 and e_2 respectively in the discussion that follows. The ratio of the second to the first is $3/2 = 1.5$, and, as we feared, it does exceed unity.

The question at issue is the following: Is 1.5 sufficiently greater than 1 as to be an unlikely ratio of variance estimates for two samples of the given sizes from the same lot, or from lots of the same variability?

Before we can go further, we must be able to decide when an observed ratio for two variance estimates is an unlikely one if the two samples are from the same lot. This question can be answered by means of the F test, in the case where the parent lot is a normal one, i.e., a lot in which the deviations from the mean obey the Gaussian or Normal Law of Errors.

The quantity F is defined as the ratio of the variance estimates for two samples of sizes $n_1 + 1$, $n_2 + 1$. For samples taken from one normal lot, mathematical theory enables us to find, for each pair of numbers n_1, n_2, a curve such as that shown in Figure 1.

Values of F are tabulated* with reference to two positive integers n_1 and n_2 and for stated **levels of significance** such as .05 and .01. The numbers n_1 and n_2 are the numbers of degrees of freedom associated with the two estimates of variance whose ratio is represented by F; in using a table of F, n_1 is **always** to be associated with the larger estimate of variance, n_2 with the smaller estimate. A value of F corresponding to two numbers n_1, n_2 and a significance level .05 is that value of F_0 (Fig. 1) for which $P = .05$; this value of F will hereafter be denoted by $F_{.05}$. Similarly $F_{.01}$ will denote the value of F corresponding to n_1, n_2 and $P = .01$.

*See, for example, Table VIII, Industrial Statistics, H. A. Freeman, John Wiley and Sons, New York, 1946.

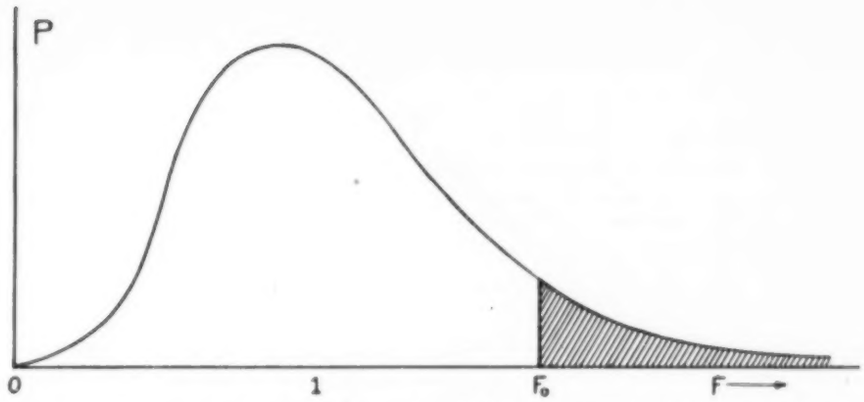


FIGURE 1 — Form of a Distribution Curve for the Ratio F of Lot Variances Estimated from Two Samples of Sizes $n_1 + 1$, $n_2 + 1$. The Shaded Area Measures the Chance P of F Exceeding F_0.

Let us now return to a consideration of the two samples of sizes 6 and 10, referred to above. They give the two variance estimates $e_1 = 2$ with 5 degrees of freedom, and $e_2 = 3$, with 9 degrees of freedom. If we regard them as two random samples from one normal lot, we find the observed ratio $F = 1.5$ for $n_1 = 9$, $n_2 = 5$. From tables of F, we find $F_{.05} = 4.78$ for $n_1 = 9$, $n_2 = 5$. Since the observed ratio 1.5 is less than the $F_{.05}$ value, we say that this observed ratio is not **significant** at the .05 level. We conclude that our data provide no convincing evidence that the unskilled workmen made articles which are more variable with respect to the measured characteristic than did the experienced workmen.

A few words of explanation may be in order at this stage. Suppose that a large number of pairs of samples, such as the above pair, are taken from one normal lot. Each pair provides two estimates of the lot variance, e_1 with 5 degrees of freedom, and e_2 with 9 degrees of freedom. The fact that $F_{.05} = 4.78$ for $n_1 = 9$, $n_2 = 5$ means that, on the average, in 5 out of every 100 pairs, the observed ratio e_2/e_1 could be expected to exceed 4.78 by chance alone. This ratio would certainly be expected to exceed 1.5 more frequently than 5 times out of 100, and we cannot say that 1.5 is an unlikely ratio of estimated variances for two samples of the given sizes from one lot. A horse which wins more frequently than 5 out of every 100 races is not particularly a long shot. If, in any case, we wish to be very sure that a long shot has come through, or that an unlikely F ratio has been obtained, we would use $F_{.01}$ rather than $F_{.05}$.

In the above example, we were concerned with the question: Is the second lot (made by unskilled workmen) more variable than the first? More precisely, we ask: Is the ratio of the variance estimates (second to the first) significantly greater than 1? We are willing to believe that the introduction of unskilled workmen has increased the variability, but not the reverse. A value of F less than one, which can readily happen by chance, would not concern us. A value significantly greater than one we would accept as reasonable proof that the variability had increased. A value of F so low that it could hardly be explained on a chance basis would not lead to the conclusion that the variability had decreased, but rather that there was something wrong with the data or our method of analysis, and that no sound basis existed for the usual F test. This is the situation in applications of the F test in the analysis of variance. If we concede that a computed value of F is significantly low, we concede that our whole experiment or method of analysis is at fault.

Sometimes, however, we wish to compare two variances in circumstances where either one may be the greater. In such a case we ask: Is the ratio of the variance estimates significantly different from 1? The appropriate form of the F test, in this case, may be called a **two-tail F test** to distinguish it from the **one-tail F test** outlined above.

For a two-tail test, the F tables will give an upper .05 limit by the usual procedure and a lower .05 limit by interchanging the numbers of degrees of freedom and taking the reciprocal of the $F_{.05}$ value obtained.* This interchange will be effected automatically if the rule is followed of always associating n_1 of the F table with the larger variance estimate when using the usual tables.

The procedure can be explained with reference to the numerical example just considered. For $e_2/e_1 > 1$, n_1 is 9, n_2 is 5, and $F_{.05} = 4.78$, which gives the upper .05 limit. For $e_2/e_1 < 1$, n_1 is 5, n_2 is 9, $F_{.05} = 3.48$, and the lower .05 limit is $1/3.48$. Thus, we expect that in the long run the ratio e_2/e_1 will fall outside the limits $1/3.48$ and 4.78 for 10 out of 100 pairs of samples.

Thus, in this two-tail test, a value such as 4.79 is not significant at the .05 level but is significant at the .10 level, although it would be significant at the .05 level in a one-tail test. It is therefore necessary to decide in a given instance which is the appropriate test to apply.

The results of the tests explained in this section can be obtained in other ways. In cases where a sufficient number of samples are available, a control chart for σ can be plotted. Lack of control in the σ chart would be indicative of differences in the corresponding lot variances.

DIFFERENCE OF TWO LOT MEANS

Suppose that from each of two lots, which we shall refer to as lots 1 and 2, we have taken a sample of six individuals and arrived at the sample data shown in Table I. From the mean values calculated in Table I, Table II may be constructed.

*Alternately, the reciprocal of the computed F may be compared with the $F_{.05}$ value obtained.

TABLE I. SAMPLE VALUES AND THEIR MEANS

	Sample from Lot 1		Sample from Lot 2	
	X-values	Deviations	X-values	Deviations
	21	−1.5	23	−0.5
	22	−0.5	25	+1.5
	25	+2.5	23	−0.5
	22	−0.5	25	+1.5
	23	+0.5	22	−1.5
	22	−0.5	23	−0.5
Sum	135	0	141	0
Mean ($\bar{X}$)	22.5		23.5	
Degrees of Freedom		5		5

TABLE II. SAMPLE MEANS AND THEIR MEAN

	Means of Samples ($\bar{X}$-values)	Deviations of Means
From Lot 1	22.5	−0.5
From Lot 2	23.5	+0.5
Sum	46.0	0
General Mean	23.0	
Degrees of Freedom		1

Now let us suppose that from our knowledge of the origin of the two lots, we are willing to assume that the variances in the two lots have the same value $(\sigma')^2$, but ask the question: Do the two lots have mean values which differ from each other?

Again, we reach a decision by a comparison, using a one-tail F test, of two estimates of the common variance $(\sigma')^2$ in either lot. The first of these estimates is obtained by considering the deviation of the two sample means from their mean value; it will tend to be an **overestimate** if the two lot means are different. The second estimate of $(\sigma')^2$ is obtained by considering the deviations of the sample values from their respective sample means; it will be unaffected by a difference in the two lot means. Thus, the ratio of the first to the second variance estimate will **tend** to exceed unity if the two lot means are different.

For our first estimate we take

$$e_1 = 6[(0.5)^2 + (0.5)^2]/1 = 3.0,$$

where the divisor is the number of degrees of freedom of the two deviations that are squared, and the factor 6 allows for the fact that we are estimating a variance of individual values from the deviations of mean values of 6.*

To find a second estimate of the variance $(\sigma')^2$ in either lot, we note that each sample provides one such estimate. The first sample gives the estimate

$$[(1.5)^2 + (0.5)^2 + (2.5)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2]/5 = 1.9$$

while the second sample gives

$$[(0.5)^2 + (1.5)^2 + (0.5)^2 + (1.5)^2 + (0.5)^2 + (0.5)^2]/5 = 1.5.$$

These are independent estimates of the same variance† and are based on the same sample size**, so we average them to obtain the required second estimate of $(\sigma')^2$, viz,

$$e_2 = (1.9 + 1.5)/2 = 1.7.$$

It will be noted that our second estimate of $(\sigma')^2$ is obtained in effect by adding the squares of all 12 deviations of the sample values from their respective sample means and dividing the result by the total number of degrees of freedom for

*This corresponds to the well-known formula $\sigma^2/\sqrt{n}$ for the standard deviation af a mean. Since variance is the square of a standard deviation, n rather than $\sqrt{n}$ is used as a factor.

†A comparison of these two estimates of lot variance, using a two-tail F test, can be made to test the validity of our assumption that the variances of the two lots are equal.

**The treatment of unequal samples may be found in appropriate texts.

such deviations, viz, $5+5=10$. This estimate, being due to variations within each sample, may be said to estimate the **within sample variance**; the first estimate, obtained from the two sample means, is due to the variation between such means, and so may be said to estimate the **between sample variance.**

The ratio of the first to the second estimate of $(\sigma')^2$ is

$$e_1/e_2 = 3.0/1.7 = 1.76$$

(approximately). We can test this ratio to see if it is significantly greater than 1 by employing the one-tail F test and using $F_{.05}$ for $n_1=1$, $n_2=10$. (The larger variance estimate is e_1 and the corresponding number of degrees of freedom is 1.) We find $F_{.05}=4.96$ which exceeds 1.76. We conclude that 1.76 is not significantly greater than 1, in this case. Thus, we cannot say that there is convincing evidence that the two samples were taken from lots with different mean values.

DIFFERENCE OF TWO LOT MEANS—ALTERNATIVE COMPUTATION

The method of computation which will be used in the remainder of these discussions, and which is convenient for handling more complicated examples, may be illustrated by recomputing the results of the previous section as shown in Tables III and IV. This method does not differ in principle from that already explained, and it gives the same numerical results. For simplicity in arithmetic, the computation is done with **coded** values and their totals, rather than with deviations and mean values.

Table III gives the sample X-values in coded form. Coding may involve addition or subtraction of a constant for all X-values and/or multiplication or division of all X-values by a constant factor. The F values are unaffected by any or all of these operations*. From these coded X-values, certain basic sums of squares, Q_1 Q_3 and Q_5, are calculated. The method of calculating these sums should be clear from Table III, and general formulae for them are given in a legend below the table. (In these formulae, the symbol Σ is an instruction to add all items of the type appearing immediately after that symbol. The symbols Q_2 and Q_4 are reserved for more complicated analyses, which will be discussed later.) It should be noted that in computing any basic sum of squares, one divides by the number of X-values used in arriving at each quantity to be squared. Thus Q_3 is formed from a sum of terms C^2, where C is a column total and, in the present case, is the sum of six X-values. We therefore divide by 6 in computing Q_3. (This corresponds to the factor 6 used in forming the first estimate in the preceding computation.)

The basic sums of squares, computed in Table III, are used to set up an analysis of variance table—Table IV. In this table, the sum of squares column may be added to give a partial check on the computations. The degrees of freedom are also additive. The number of degrees of freedom for the total is one less than the number of X-values, the number of degrees of freedom for columns is one less than the number of columns, and the number of degrees of freedom for residual may be obtained by subtraction.

The mean square values in the fourth column were called variance estimates in the previous treatment. They are estimates or overestimates of the same quantity, and consequently not additive (e.g. $20/11=1.81$, $3+1.7=4.7$).

The F values are the same as previously calculated, and lead to the same conclusion that there is no significant difference between means.

*Multiplication or division by a constant multiplies or divides all sums of squares and mean squares in the analysis of variance table by the same constant squared.

TABLE III

COMPUTATION OF BASIC SUMS OF SQUARES—DIFFERENCE OF TWO MEANS

(Values in Table I, coded by subtracting 20)

	Sample From Lot 1		Sample From Lot 2		Totals	
	X	X^2	X	X^2		
	1	(1)	3	(9)		
	2	(4)	5	(25)		
	5	(25)	3	(9)		
	2	(4)	5	(25)		
	3	(9)	2	(4)		
	2	(4)	3	(9)		
Totals C	15	(47)	21	(81)	36	(128)*
C^2	225		441		666	

$Q_1 = \Sigma X^2/1 = 128/1 = 128$ (X = Individual Value)
$Q_3 = \Sigma C^2/6 = 666/6 = 111$ (C = Column Total)
$Q_5 = T^2/12 = 36^2/12 = 108$ (T = Grand Total)

*The bracketed numbers are used in arriving at the sum of squares of the tabulated values.

TABLE IV

ANALYSIS OF VARIANCE TABLE—DIFFERENCE OF TWO MEANS

	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{.05}$
Columns (samples)	$Q_3-Q_5=3$	1	3	1.76	4.96
Residual (within samples)	$Q_1-Q_3=17$	10	1.7		
Total	$Q_1-Q_5=20$	11			

TABLE V

COMPUTATION OF BASIC SUMS OF SQUARES—SINGLE CLASSIFICATION
Column (Assembly Line)

	1		2		3		4		5		Totals	
	X	X^2	X	X^2	X	X^2	X	X^2	X	X^2		
	4	(16)	3	(9)	6	(36)	4	(16)	6	(36)		
	4	(16)	1	(1)	6	(36)	4	(16)	6	(36)		
	3	(9)	2	(4)	6	(36)	6	(36)	8	(64)		
C	11	(41)	6	(14)	18	(108)	14	(68)	20	(136)	69	(367)*
C^2	121		36		324		196		400		1077	

$Q_1 = \Sigma X^2/1 = 367$ (X = Individual Value)
$Q_3 = \Sigma C^2/3 = 1077/3 = 359$ (C = Column Total)
$Q_5 = T^2/15 = 69^2/15 = 317.4$ (T = Grand Total)

*The bracketed numbers are used in arriving at the sum of squares of the tabulated values.

TABLE VI

ANALYSIS OF VARIANCE TABLE (COLUMN OR ASSEMBLY LINE EFFECTS)

	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{.05}$
Columns (Assembly Lines)	$Q_3 - Q_5 = 41.6$	4	10.4	13	3.48
Residual (Within samples)	$Q_1 - Q_3 = 8$	10	0.8		
Total	$Q_1 - Q_5 = 49.6$	14			

DIFFERENCES OF LOT MEANS IN A SINGLE CLASSIFICATION

Suppose that in a certain factory there are five different assembly lines producing the same type of article. We may consider an hour's production of the factory to consist of five lots, each lot being from a different assembly line. If a sample of three articles is taken at random from each lot and a certain characteristic of each article measured, we get a set of 15 numbers which can be divided into five groups of 3, one group from each lot or assembly line. Such a classification of data with the aid of a single criterion is called a single classification. In the next section we shall deal with the classification of data using two criteria—a so-called **two-way classification.**

We wish to know if the means of the five lots are different or, in others words, if the five assembly lines were operating at different levels of the characteristic in question.

The situation is much the same as in our example of samples from two lots considered earlier. The only differences are (1) we have five possibly different lots instead of two, and (2) each sample consists of three values in place of six.

We follow the alternative plan explained in the preceding section and obtain the analysis shown in Tables V and VI. The numerical values entered as X-values in Table V were obtained by making 3 draws from each of 5 lots (assembly lines) of chips. The chips in each lot were marked with numbers so that each lot had unit variance; the true means for the several lots were 3, 4, 5, 6, and 7, respectively. In this case, there was no need for coding these values.

Note that the order in which the X-values are entered in a column in Table V has no effect on this method of analysis. It is assumed that all within-column variation is random.

Since the F-value of 13 far exceeds the value 3.48 for $F_{.05}$, we conclude that the variance estimate or mean square 10.4 is significantly greater than 0.8. Hence, we have reason to believe that there is a difference in the mean values for the several assembly lines, or that there is an assembly line effect. In practice, we would then seek to determine why the several assembly lines were producing different articles, and try to remove the causes of such non-conformity.

DIFFERENCES OF ROW AND COLUMN MEANS IN A TWO-WAY CLASSIFICATION

If the sample data from the five assembly lines, considered above, were obtained by dividing the hour into three periods and choosing one article from each line in each period, we could then divide our data into 3 groups of 5 articles each. Each group of 5 articles would then correspond to one of the three periods into which the hour was divided. The previous classification into 5 sets of 3 according to assembly lines, still holds. In such a case, we have our data classified in two ways, and can arrange it in rows and columns as shown in Table VII, where the same numerical values are used for convenience.

We could, of course, consider each classification separately, and do two analyses similar to that in Table VI — one for column effects

TABLE VII

COMPUTATION OF BASIC SUMS OF SQUARES (SINGLE AND TWO-WAY CLASSIFICATION)

Column (Assembly Line)

		1		2		3		4		5		Totals	
		X	X^2	X	X^2	X	X^2	X	X^2	X	X^2	R	R^2
Row (Selection Period)	1	4	(16)	3	(9)	6	(36)	4	(16)	6	(36)	23	529
	2	4	(16)	1	(1)	6	(36)	4	(16)	6	(36)	21	441
	3	3	(9)	2	(4)	6	(36)	6	(36)	8	(64)	25	625
Totals	C	11	(41)	6	(14)	18	(108)	14	(68)	20	(136)	69	1595
	C^2	121		36		324		196		400		1077	(367)*

$Q_1 = \Sigma X^2/1 = 367$ (X = individual Value)
$Q_3 = \Sigma C^2/3 = 1077/3 = 359$ (C = Column Total)
$Q_4 = \Sigma R^2/5 = 1595/5 = 319$ (R = Row Total)
$Q_5 = T^2/15 = (69)^2/15 = 317.4$ (T = Grand Total)

*The bracketed numbers are used in arriving at the sum of squares of the tabulated values.

TABLE VIII

ANALYSIS OF VARIANCE TABLE (ROW AND COLUMN EFFECTS)

	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{.05}$
Columns (Assembly Lines)	$Q_3 - Q_5 = 41.6$	4	10.4	13	3.84
Rows (Time Periods)	$Q_4 - Q_5 = 1.6$	2	0.8	1	4.46
Residual	$Q_1 - Q_3 - Q_4 + Q_5 = 6.4$	8	0.8		
Total	$Q_1 - Q_5 = 49.6$	14			

and one for row effects. This procedure is unsatisfactory, however, if there exist both row and column effects, and the analysis given in Tables VII and VIII should always be used.

In Table VIII, the sum of squares $Q_3 - Q_5$ leads to a mean square or variance estimate due to differences between mean values of the five columns, the sum of squares $Q_4 - Q_5$ is due to differences between row means, and the residual sum of squares $Q_1 - Q_3 - Q_4 + Q_5$ is due to differences among sample values after row and column effects have been deducted. On the assumption that no interaction* is present, each of the first two mean squares can be divided by the residual mean square to give an F value. If this exceeds the corresponding $F_{.05}$ value, then we conclude that there is a significant row or column effect, as the case may be.

If interactions are actually present, then our test will be less sensitive and we may be testing at a level materially below .05. We may also expect more frequent extremely low values of F than if interactions are absent.

Clearly, Table VIII shows a significant column or assembly line effect but no row effect. Since each of the three values in a column of Table VII was actually drawn from the same lot, we would not expect a row effect.

AN EXTENSION COURSE IN STATISTICAL QUALITY CONTROL AND SAMPLING INSPECTION

A. E. R. Westman
Director of Chemical Research
Ontario Research Foundation

Price: $1.25 per copy

Order from:

MANUFACTURING AND INDUSTRIAL ENGINEERING
73 Richmond Street W.
Toronto, Canada

It may be noted that the first test for column effect only, Table VI, assuming randomness within columns, corresponds to an $\overline{X}$ chart in quality control in which the averages for the five assembly lines would be plotted against limits calculated from within assembly line ranges or standard deviations.

The analysis of variance method has advantages when dealing with a small number of subgroups.

The second method of analysis, Table VII, has no counterpart in current control chart practice.* If the column averages are plotted against limits based on the within-column ranges or standard deviations, the limits will be too wide if row effects are present; a row average chart will similarly have limits too wide, if column effects are present.

*Interactions will be discused in Part II.

*A control chart technique for this type of problem has been developed by two of the authors and will be reported to the Society later.

Editorial note: Parts II and III will appear in the May issue of IQC.

AMERICAN SOCIETY NEWS

ANNUAL MEETING

In accordance with Section **60.a.** of the Constitution, the Board of Directors decided, at its meeting in Rochester on 16 February, that the Annual Meeting of the Society would be held in New York City on the evening of Tuesday 15th June, Wednesday 16th June, or Thursday 17th June, 1948, — the exact date to be determined when a satisfactory meeting place has been secured.

Notice of the exact time and place of the Annual Meeting will be mailed to each corporate member by the Executive Secretary prior to 1 May, along with an official ballot for the election of officers for the year 1948-49.

RECOGNITION OF SECTIONS

At the meeting of the Board of Directors of the Society held in Rochester on 16 February, recognition was extended to the new Dayton and Mid-Hudson Sections. In accordance with Section **10.c.** of the Constitution, the Board also withdrew the privileges of the Omaha Section. The Society thus now has thirty active Sections.

CODE OF ETHICS ADOPTED

At the Dinner Meeting of the Society held in connection with the Annual Convention in Rochester on 16 February, President Edwards announced that the Board of Directors had unanimously approved the Code of Ethics as submitted and recommended by the Committee on Professional Ethics and Qualifications and endorsed by the Executive Committee. The Code was printed in full on page 30 of the January 1948 issue of the magazine, and now stands adopted as the Code of Ethics of the Society.

DR. SHEWHART HONORED

Dr. Walter A. Shewhart, a Fellow and Honorary Member of the Society, and a member of its Advisory Council, was appointed by the President as a delegate to the first General Assembly of the Inter-American Statistical Institute held in Washington during the week of 10 September.

In this capacity, Dr. Shewart also attended the meetings of the International Statistical Congress, called jointly by UNESCO, the International Statistical Institute, and the Inter-American Statistical Institute, and held in Washington during the same week.

Dr. Shewhart is now in India, on loan from Bell Telephone Laboratories to the government of the Dominion of India, for consultation in connection with the introduction of Quality Control into Indian Industry.

ST. LOUIS SECTION MAKES SUSTAINING CONTRIBUTION

The members of the St. Louis Society for Quality Control have generously voted and paid to the American Society a sustaining contribution of fifty dollars out of the proceeds of their First Annual Quality Control Clinic which was held at the DeSoto Hotel in St. Louis on 21 November, 1947.

STANDING COMMITTEES

The November issue of the magazine listed all Standing Committees of the Society for 1947-48 with the exception of the Nominating Committee.

At the December meeting of the Executive Committee, the President submitted proposed appointments to the Nominating Committee, and these were unanimously approved as follows:

Nominating Committee

Elwood E. Folsom, Jr., Chairman
Ralph A. Hefner
Wyatt H. Lewis
Paul S. Olmstead
Ernest H. Robinson
Herbert G. Winter
George D. Edwards (ex officio)

Any member of the above Committee will be glad to receive suggestions from any member or members of the Society with regard to desirable nominees for any office. Such suggestions, in writing, may also be addressed to

Mr. E. E. Folsom, Jr.
c/o General Electric Co.
1285 Boston Avenue
Bridgeport 2, Connecticut.

In this connection, members should have in mind the constitutional provision making the present President of the Society ineligible for reelection. There is no such prohibition with regard to reelection of any of the other present officers.

GENERAL COMMITTEES

The November issue of the magazine listed all General Committees of the Society for 1947-48 with the exception of the Committee on Publicity and Public Relations. President Edwards has now announced completion of that Committee as follows:

Committee on Publicity and Public Relations

Vice-President and General Chairman
Frederick J. Halton, Jr.

Executive Chairman
Ernest H. Robinson

New England
G. R. LaWall, Regional Chairman
Charles L. Garbarino
H. L. McChesney
H. Melkonian

Middle Atlantic
H. W. Poole, Regional Chairman
A. G. Dalton
P. M. Dickerson
L. F. Knudsen
Everett V. Lewis
Theron M. Vining

Northern
Earl F. Graumenz, Regional Chairman
Oscar L. Anchors
Howard M. Craig
Edwin P. Mynott
James M. Persons
John Sleith

Central
Guy W. Abson, Regional Chairman
Emil F. Gibian
Ross Martin, Jr.
James A. Mitchell

Mid-West
Charles O. Menzel, Regional Chairman
Clarence J. Armstrong
P. M. Brink
E. J. Cade

William A. Faser
Ernest L. Fay
Paul H. Hargitt
Ernest H. Robinson

Western
Carl M. Boswell,
Regional Chairman

JOINT AIEE-ASQC ACTIVITIES

The AIEE Sub-Committee on Application of Statistical Methods, under the able Chairmanship of Mr. W. P. Dobson, Director of Research of the Ontario Hydro-Electric Power Commission, has recently made a number of constructive proposals for more active AIEE-ASQC cooperation at a national level.

To implement these, Mr. A. G. Ashcroft, Executive Chairman of the ASQC Committee on Relations with Other Technical Societies, has appointed a Sub-Committee on General AIEE Relations, composed as follows:

P. S. Olmstead, Chairman
E. E. Folsom, Jr.
E. H. MacNiece

On 14 January, 1948, the AIEE and ASQC Sub-Committees met jointly in New York to consider the AIEE proposals in detail. Specifically, these proposals involved presentation at AIEE District Meetings of papers on the actual use of statistical methods in factory control of the quality of products in the electrical field. Sessions for the presentation of these papers would have joint AIEE-ASQC sponsorship. The thought of the Joint Sub-Committee is that these papers would be presented as parts of sessions on various subjects. For instance, sessions devoted to wires and cables might include a paper on some application of Quality Control through Statistical Methods by a cable manufacturer. Similarly, a session devoted to communications problems might include a paper on some outstanding application in that field.

The ASQC Sub-Committee will welcome suggestions concerning papers for such programs from engineers who are utilizing Statistical Quality Control Methods in Electrical Engineering. Such suggestions may be sent to any one of the members of the ASQC Sub-Committee listed above.

NEW INFORMATION FOLDER AND APPLICATION BLANK

A new edition of the "Information Folder" regarding the Society is now available, and copies may be obtained without charge from the Executive Secretary. The new edition is rather more attractive and considerably more complete than was the earlier one, and it should be helpful to membership committees and others in securing new members for the Society.

A new general "Application Blank" for admission as a Member of the Society, or for transfer from the Member to the Senior Member grade, is now available and copies may be obtained from the Executive Secretary. In addition to space for filling in the necessary information, the new blank summarizes the qualification requirements for the several grades of corporate membership. The Blank has been printed in two forms. The first form, for use by the Executive Secretary's office, shows the dues payable by American Society members "At-Large" in the several grades, and indicates that, upon completion, the blank should be returned to the Executive Secretary in New York. The second form, intended for use by local Sections, leaves blank spaces where the total Section and American Society dues, and the address of the Section Secretary, or Membership Chairman, may be inserted by rubber stamp.

It is suggested that Section Membership Chairmen have copies of the "Information Folder", and of the second form of "Application Blank", available at all Section and other meetings for individual distribution to prospective members or transferees. In distributing the Application Blank, care should be taken to insure that the proper dues amounts and return address are inserted on all copies.

MEMBERSHIP RENEWALS AND NEW MEMBERS FOR 1947-1948

As of 1 February, 950 of the 1946-47 members of the Society had paid dues for 1947-48. This represents just 49% of the 1946-47 membership.

Sectionwise, renewals continued extremely spotty. Only one Section, Western Massachusetts with 89%, had re-enrolled as much as three-quarters of its 1946-47 membership, though twelve other Sections had attained or exceeded 50%. On the other hand, one Section had re-enrolled no members whatever as of the date mentioned, and two others had attained only about 20%. Obviously, there is some real work to be done on this matter in a number of Sections.

The situation with respect to new members continued to be much more encouraging. As of 1 February, 653 members not previously identified with the Society had paid dues for 1947-48. The hoped-for continuance of the ratio of two new members for each three renewals, was thus still a fact. Here again however, the situation continued extremely spotty.

Five Sections are to be congratulated on having as many or more paid-up members for 1947-48 than they had in 1946-47,—Western Massachusetts with 228%, Indiana with 190%, Ohio with 153%, Syracuse with 101%, and St. Louis with 100%. However, three Sections still show less than half as many 1947-48 members as they had in 1946-47, and a fourth Section still has no 1947-48 members whatever.

As of the date mentioned, total American Society membership for 1947-48 stood at 1603, or 83% of the final 1946-47 figure.

TRANSFERS TO SENIOR MEMBERSHIPS

As of 1 February, 586 or 62% of the 950 1946-47 American Society members who had paid their 1947-48 dues, had transferred to the Senior Member or Fellow grade. As with renewals, the showing of the various Sections continues very spotty in this matter. Iowa is in the lead with 96% of its re-enrolled members transferring, but it is closely followed by Philadelphia with 95%, Georgia and Western Massachusetts with 94% each, and Chicago and Ohio with 86% each. On the other hand, one Section with over 50% of renewals shows only 2% transfers, and three others

with 45% to 60% of renewals show only about 10% of transfers.

If the Society is to meet its budget and continue successful, at least half its membership must be in the Senior Member and Fellow grades. This means that at least two-thirds of the re-enrolling members must transfer.

The Six Sections mentioned specifically above, have definitely proved that the goal of the Society is attainable if the necessary effort is put forth in securing transfers to Senior Membership. It is hoped that all of the Sections will follow their fine example. It is believed that the great majority of re-enrolling members will be found willing to transfer to the Senior Member grade if it is pointed out to them that they are not fully paying their own way in the Society unless they do so.

TRANSFERS TO FELLOWSHIP

The Examining Committee has prepared a temporary "Supplementary Application Blank" and "Information Sheet" for use in connection with applications for transfer to the grade of Fellow in the Society.

Copies of the supplementary blank and information sheet have been sent by the Executive Secretary to all members who have made advance written application for such transfer. In addition, a number of copies of the blank and information sheet have been forwarded to the secretary of each Section so that they can be made available to members interested.

A considerable number of applications for Fellowship is already in the hands of the Examining Committee. These will be considered in turn as rapidly as the Committee is able, and each member concerned will be notified by the Executive Secretary immediately following favorable action on his application. It is obvious, however, that the first flood of applications for transfer has imposed a huge burden of work on the Examining Committee, and that some considerable time may elapse before all applications now in hand are cleared. It is hoped that applicants will be patient with the Committee in the circumstances, since the Committee has a sober obligation to the Society to insure that only fully qualified applicants are accepted for transfer.

In the meantime, all applicants for transfer to Fellowship who receive formal notice of favorable action on their applications, are urged to accept promptly and to remit the difference in dues, so as to insure their proper entry in the forthcoming Year-Book.

Book Review

CONTROL CHARTS: An Introduction to Statistical Quality Control. Ed Smith. McGraw-Hill, New York, 1947; 161 pp; $3.00. Review by Professor John A. Henry, College of Engineering, University of Illinois.

Two years ago one could look in vain for a book on statistical quality control that was designed for the non-technical reader. Since that time, several texts have been published to help bridge the gap between the applied statistician and the layman. Edward S. Smith, Professor of Mathematics at the University of Cincinnati, is well qualified to build that bridge. He is known as a successful textbook author and as a veteran teacher of mathematics to beginning college students. Professor Smith knows all the mental blocks that a student can place in the way of understanding mathematical processes. During the war, he assisted one of the large industries in the training of factory personnel for quality control.

This book is one of the McGraw-Hill Organization and Management Series, and is in the author's words, "A Text for the Busy Executive." It is stated that the material will also be suited for use in in-plant training of operating men. This short book is devoted entirely to the control chart, and is divided into five chapters.

Chapter I is entirely non-mathematical and serves as an introduction to the subject. It deals with the historical development of the control chart system, gives something of the underlying philosophy, and ends with a summary of the benefits to be derived from intelligent use of the charts.

Chapter II is entitled "Frequency Distributions." It starts with some simple examples and leads up to the normal curve. Some comparisons of different distributions with tolerance are introduced to gain the confidence of the "practical" man. In this chapter, the author begins to bring in the idea of limits by referring to "danger limits," which are the three-sigma limits for individuals.

Chapter III, "Control Charts for Averages and Ranges," starts with a discussion of inspection by attributes and variables, and then proceeds to develop the construction and use of the measurements chart. There is in the writer's mind a feeling that the simplification of the spread of control limits by referring to it as $\pm Y_A$ and $\pm Z$ is in the long run an unnecessary complication of the standard nomenclature. The latter is, of course, properly introduced a bit later. Professor Smith has done a good job of showing how control limits and specification limits are related, and how to squeeze the last bit of blood out of a tight specification. However, to a beginner, it might appear that every process is in a life-and-death struggle with tolerances. While this is far from true, the emphasis on close tolerances is probably well made, for most chart applications will be made under those conditions, real or imagined. The chapter ends with some of the better known experimental techniques of dice and numbered discs. It is possible that many production men would disagree with Professor Smith about the relative value of the averages and range charts. The maintenance man and trouble shooter frequently uses the range chart for his guide, whereas the process inspector is more concerned with the average level. It goes back to the

two fundamental purposes of the charts, so admirably stated in the pamphlets of the American Standards Association.

Chapter IV deals with charts for fraction defective, number of defectives, and number of defects per unit. The author proposes the substitution of **m** for the more familiar notation **pn**. This chapter develops the necessary mathematics in a painless method, and develops the basic concepts in a clear manner. However, in view of the present rather primitive method of writing lot specifications, a word of explanation is in order when discussing specifications for attributes inspection. Perfection is still the dream of many people who ought to know more about economic production.

Chapter V is called "Three-Sigma Limits." It presents for the more earnest reader the meaning of standard deviation, and shows how to use the standard deviation of a sample instead of the range as a measure of dispersion. The book ends with three tables. The first is a standard table of squares, square roots and reciprocals. The second is a convenient table for the spread of control limits for the fraction defective chart, with various sample sizes and average quality levels. The third table is the standard list of factors for computing limits for average and range charts. A new column, D, has been added.

The opening chapter provides a basis for some serious thinking. From Shewhart's book to the present day, various authorities have sought to present the basic concepts and definitions in an ever-clearer fashion. If a major fault could be found in the book, it is that of oversimplification at this point. A definition of statistical control should have in it somewhere an implication of a constant system of chance causes. Eventually, if one is to grasp the significance of the control chart technique, one must face this idea and have it out. It seems better to give a definition that cannot be comprehended immediately, but is worked out as a purpose of the book rather than to give a substtute definition that does not stand up under subsequent study. Similarly, and this is true of all books that have come under the writer's observation, the definition of **quality** is a difficult task. Again referring to Shewart, the "quality" of quality control is essentially a mass phenomenon, or more simply, a matter of frequency distribution. Someone should get busy on these frequently used words, but perhaps the field is still too young for standardization.

It may never be possible to write a perfect book for the busy executive on such a technical subject. Chapter I., which is **his** chapter, could well have included some of the typical problems that a control chart would help to solve, when faced with a production or inspection decision. While this deficiency of economic and philosophical ideas may keep the book from being of maximum benefit to the management group, the technical portions are admirably suited to an in-plant training program.

Forthcoming Lectures and Courses in Statistical Quality Control

LECTURES ON INDUSTRIAL STATISTICS

The **Massachusetts Institute of Technology** announces two series of lectures on statistical methods by L. H. C. Tippett, Chief Statistician, British Cotton Industry Research Association, and an address by Walter A. Shewart, Bell Telephone Laboratories.

First Series
Statistical Methods for Industrial Quality Control

Topics covered will include: the specification of quality by statistical measures—frequency distributions, averages, measures of variation, percentages defective; the relations between tolerances and the percentage defective; control charts, their construction and interpretation — percentage defective, average, range, special adaptations; sampling schemes — single, double, and sequential. The rationale of quality control will be emphasized. A knowledge of elementary algebra, of simple averages, and of the elementary notions of probability will be assumed.

Wednesday, May 5, 1948, through Friday, May 7, 1948, 3-5 P.M. Room number 6—120. Fee: $15.00 per person.

Second Series
Statistical Methods for Technical Investigation and Experimentation

The treatment of experimental and observational errors by statistical sampling theory, the effect of errors on inferences, the tests of significance, and the design of investigations and experiments to make inferences valid, will be explained with reference to the simple comparison of the effects of two experimental treatments. More complicated investigations and experiments to investigate assignable causes of variation and to measure their importance, involving the statistical methods of correlation and the analysis of variance, will be explained. The subject will be dealt with theoretically and practically, and illustrations will be taken from the factory and laboratory. Knowledge of the subject matter of the first series and of algebra will be assumed.

Wednesday, May 12, 1948, through Friday, May 14, 1948; 3-5 P.M. Room number 6—120. Fee: $15.00 per person.

Each of the above series of lectures will be conducted by Mr. Tippett, and are intended to be introductory, with numerous illustrative examples. Mr. Tippett will be available for discussion for about one half hour after each lecture.

An Address on
The Future of Statistics in Industrial Research and Quality Control

There will be a dinner meeting, open to persons interested in statistical methods in quality control and experimentation, in the Campus Room of the Graduate House, Massachusetts Institute of Technol-

ogy, on Friday, May 14, 1948, at 6:00 P.M. Walter A. Shewhart, Bell Telephone Laboratories, will address the audience on the subject stated above. The fee for the dinner meeting is $3.00 per person, including taxes and tips. This meeting will be limited to 200 persons.

Payment of fees for these meetings should be made by April 23, 1948. Make checks payable to D. L. Rhind, Bursar, and send them and all other correspondence to H. A. Freeman, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

BASIC TEN-DAY COURSE IN STATISTICAL QUALITY CONTROL

The Extension Class Division of the University of Illinois is offering its third basic course in Statistical Quality Control from June 8 to June 18, 1948. Full time instructors for the course will be John A. Henry, Department of Mechanical Engineering, University of Illinois; Mason E. Wescott, Department of Mathematics, Northwestern University; Irving W. Burr, Department of Mathematics, Purdue University; and Lloyd A. Knowler, Department of Mathematics, The State University of Iowa. Speakers from industry will present selected topics. Enrollment is limited to 50 students from industry and carries no university credits.

The course will cover control charts and sampling plans, together with some application to engineering specifications and tolerances. The outlines of previous courses are being studied to provide maximum benefit to those moderately familiar with the program as well as those for whom it will be a first introduction. The tuition will be $100.00 per man, including cost of texts, materials and instruction. Full information about the course may be obtained by writing to Mr. H. C. Rountree, Director of Extension Classes, 118A Illini Hall, 725 S. Wright St., University of Illinois, Champaign, Illinois.

Academic Scholarships

As a new service which should benefit both industry and education, the Extension Class Division is offering up to five academic "scholarships" for this course. Persons engaged in teaching statistical quality control in a bonafide college or university or who plan to teach such courses, may apply to Mr. Rountree. The $100.00 tuition fee will be waived, the student paying only for the actual texts and materials used, and of course, his own travel and sustenance. In case more apply than can be accommodated the extension division will decide on the relative merits of the applicants. Society members are urged to present this information to those who might benefit.

EIGHT-DAY COURSE IN QUALITY CONTROL FOR THE CHEMICAL INDUSTRIES

An eight-day intensive training course in **Quality Control for the Chemical Industries** will be offered by the Rochester Institute of Technology at Rochester, New York, June 15-23, 1948. While this course will provide instruction in basic statistical control methods, it will also include many of the advanced techniques which are found useful in the chemical industries.

The course is designed for those engaged in analytical laboratory work or for those responsible for controlling quality of product where a continuous production process is involved. The Institute has sponsored three similar courses all of which have emphasized the practical applications of quality control.

The tutition of $100.00 per person includes books and supplies. Room accommodations will be available at the Hotel Rochester. Further inquiries should be addressed to the course coordinator: Alfred L. Davis, Associate Director, Evening and Extension Division, Rochester Institute of Technology, Rochester 8, New York .

ADVANCED COURSE IN STATISTICAL QUALITLY CONTROL — PURDUE UNIVERSITY

An eight-day advanced course in statistical quality control will be offered by Purdue University September 9-17 inclusive. This course is intended to meet the needs for additional training of men and women who have had some previous instruction or practical experience in the subject.

Topics to be offered are: review and background of control charts, significance of differences, principles of acceptance sampling, sequential analysis, both attributes and measurements, linear and multiple correlation, analysis of variance, tolerances of fitting parts, chi-square, and use of calculating machines.

Prerequisites are a first course or its equivalent. The emphasis will be on applications, and all techniques will be explained as simply as possible.

Instructors for the course will be: Professors Irving W. Burr, Purdue University; Lloyd A. Knowler, The State University of Iowa; Edwin G. Olds, Carnegie Institute of Technology, and Mason E. Wescott, Northwestern University.

Tuition is $100. For additional information, write to Professor Irving W. Burr, Department of Mathematics, Purdue University, Lafayette, Indiana.

SAVE TIME! **USE BENDER CALCULATOR!**

STREAMLINE YOUR CALCULATIONS!

Calculate Control Limits for RANGE, AVERAGES, and INDIVIDUALS, all in less than 30 seconds. Solve p chart limits in less than 10 seconds.

Only $2.60, including mailing . . . Order today . . . Satisfaction guaranteed

Arthur Bender, Jr., Edgewood, Anderson, Indiana

CLASSIFIED ADVERTISEMENTS

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

Management Controls

FOUNDED IN 1945

"References and Literature on Request"

Senior Partner:
W. E. JONES
Sr. Member, ASQC

699 ROSE AVE.
DES PLAINES, ILL.
DES PLAINES 1493

RALPH E. WAREHAM

CONSULTANT ON QUALITY CONTROL

305 EAST 43RD ST.
NEW YORK 17, N. Y.

TELEPHONE
MURRAY HILL 6-9044

POSITIONS WANTED

Quality Control Engineer desires position. Statistics degree, 4 yrs. exp. in metallic-chemical firm; 2 yrs. teaching exp. Write to 4E1, American Society for Quality Control, 305 East 43rd St., New York 17, N. Y.

SPECIALIST — prepares information for decision. Experienced in application of statistical method to experimental design, inspection, production control, quality control. Graduate engineer. Write to L8D-3P4, American Society for Quality Control, 305 East 43rd St., New York 17, N. Y.

Age 39; B.A., Western Reserve Univ.; M.A., Ohio State Univ., Experience: 12 yrs. Statistician; 1 yr. Time Study man; 5 yrs. Cost Estimator and Standard Cost Specialist; 6 mo. Quality Control Supervisor; Instructor at Fenn College and Cleveland College in Statistics, Quality Control, Marketing Research. Herbert E. Bender, Member ASQC, 23221 Lake Shore Blvd., Euclid, Ohio.

Quality Control Engineer; age, 33; B.E.E. degree. Experience: 9 months Quality Control; 15 months Electrical Engineering; 3 years Statistician. Write: 4E2 American Society for Quality Control, 305 East 43rd Street, New York 17, N. Y.

POSITIONS AVAILABLE

Midwestern Pharmaceutical Manufacturing concern has an opening for a graduate in General Science or Engineering. Should have at least 3 years industrial experience in operating statistical quality control, and some knowledge of setting up statistical experiments. Statistical background should include knowledge of variance and multiple correlations. Write to: 4K1, American Society for Quality Control, 305 East 43rd Street, New York 17, N. Y.

When you buy from our advertisers, mention their ads in "INDUSTRIAL QUALITY CONTROL."

Put **YOUR** Product or Services Before an Active Market

ADVERTISE

through

Industrial Quality Control

THE MAGAZINE THAT IS **READ** BY THE MEN WHO CAN **USE** YOUR PRODUCT!

For Rates and Space Address Your Inquiry To
Edward D. Thompson, American Society for Quality Control
Post Office Box, 1097, Chicago 90, Illinois

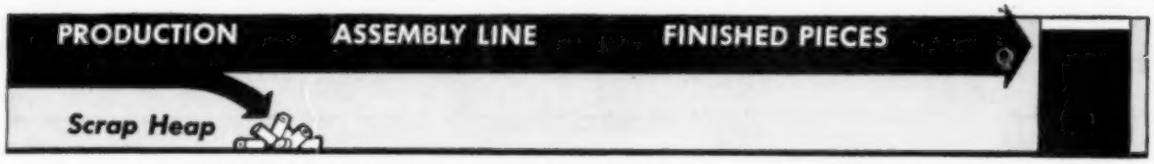
Did you ever sell SCRAP at a profit?

Your scrap pile holds more than metal. Its costly contents include your dead losses in time and labor operations. Seconds and rejects can only mean increased production costs all along the line.

There is an answer to this . . . Inspection by Dial Indicator Gaging . . . Stop making the parts that won't fit!

Wherever you have a production problem involving a dimension of any kind, you have a use for a Dial Indicator Gage. And a Dial Indicator Gage for that specific job is available . . . This is the *modern* inspection method that enables workers to see dimensions, instead of feeling for them. You get accuracy—to whatever degree your work requires. Equally important—you get speed.

Old-fashioned gaging methods permit too much scrap loss



Dial Indicator Gaging cuts seconds and rejects to a minimum

For example—as pictured at the right—a Dial Indicator permits gaging while grinding, makes possible continuous precision measurement without stopping the machine. This prevents out-of-round, oversize and undersize pieces—reduces inspection time—saves the time formerly needed for resetting sizing controls after wheel dressing. The Arnold Gage, with various accessories, accurately gages outside diameter, inside or outside widths between faces of shoulders, tapered diameters, and work having splines and keyways. For full details, please write for illustrated Bulletin No. 16.

We make both standard and custom-built gages to meet the needs of users in a hundred industries. For highly specialized needs, we also make Air Gages and Automatic Electronic Sorting Gages. Let us help you with any problem of gaging and inspection. If you will send us blueprints of work to be measured, we will gladly recommend the proper gage. No obligation is involved.

Visit our booths #314 & #413 at the A.S.T.E. Show, Cleveland, March 15th-19th

FEDERAL

FEDERAL PRODUCTS CORPORATION
1144 Eddy Street Providence 1, R. I.

YOUR PROFIT DECISION IS *Visible** PRECISION

*The use of Dial Indicator Gages—visible precision—lowers inspection costs, raises production. Federal Products Corporation is America's largest maker of both standard and custom-built gages—mechanical, air, electronic—for the measurement of single and multiple dimensions.